DOCUMENT RESUME

ED 158 985 SE 024 680

AUTHOR Schulze, Terry L., Ed.; Kriner, Ray R., Ed.
TITLE Pesticide Applicator Training Manual, Category 8B: Mosquito Control for New Jersey. A Training Program for the Certification of Commercial Pesticide Applicators, and Study Questions.
INSTITUTION Rutgers, The State Univ., New Brunswick, N.J. Cooperative Extension Service.
PUB DATE [77]
NOTE 80p.; For related documents, see SE 024 677-679

EDRS PRICE MF-$0.83 HC-$4.67 Plus Postage.
DESCRIPTORS Biology; *Certification; *Entomology; *Instructional Materials; *Pesticides; *Post Secondary Education; Public Health; Safety; *Units of Study
IDENTIFIERS Mosquitoes; *New Jersey

ABSTRACT

This training manual provides information needed to meet the minimum EPA standards for certification as a commercial applicator of pesticides in the mosquito control category. The text discusses the aspects of mosquito biology and control by biological, mechanical, and integrated measures. A study guide with sample and study questions is included. (CS)

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Pesticide Applicator Training Manual

CATEGORY 8B

MOSQUITO CONTROL

RUTGERS
THE STATE UNIVERSITY OF NEW JERSEY

SE 024 680

PESTICIDE APPLICATOR TRAINING MANUAL
CATEGORY 8B

Mosquito Control
for
New Jersey

A Training Program for the Certification
of Commercial Pesticide Applicators

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TABLE OF CONTENTS

CONTENTS	PAGES
TABLE OF CONTENTS	i-ii
LIST OF FIGURES	iii
INTRODUCTION	1- 3
IDENTIFICATION	4- 8
MOSQUITO BIOLOGY	9-20
Eggs	9-10
Larvae	10-11
Pupae	11-12
Adults	12-13
Life Cycles and Larval Habitats	13-20
Woodland Pool Mosquitoes	14-15
Floodwater Mosquitoes	16
Salt Marsh Mosquitoes	17-18
Freshwater Swamp Mosquitoes	18-19
Polluted Water Mosquitoes	19-20
MOSQUITOES AS VECTORS OF DISEASE	21-23
Mosquito-borne Encephalitides	22
Eastern Equine Encephalitis	22
St. Louis Encephalitis	22-23
Dog Heartworm	23
SURVEY METHODS	23-33
Adult Mosquito Surveillance	24-30
The New Jersey Light Trap	24-25
Landing Counts	25-27
Pigeon Baited Traps	27-28
Resting Boxes	28
Truck Traps	29-30
Larval Mosquito Surveillance	30-33
Records	33
CONTROL	33-56
Water Management	34-39
Freshwater	35
Saltwater	35-39
Ditching	36-37

CONTENTS

	PAGES
Ponding	38
Impounding	38
Chemical Control	39-49
Insecticides	39-43
Inorganic Insecticides	39-40
Organic Insecticides	40-43
Oils	40-41
Chlorinated Hydrocarbons	41
Organophosphates	41
Pyrethroids	42
Carbamates	42
Insect Growth Regulators	42-43
Herbicides	43
Repellents	43
Insecticide Formulations	43-45
High Concentrate Liquids	44
Emulsifiable Concentrates	44-45
Granules	45
Wettable Powders	45
Application Equipment	45-49
Application of Granular Formulations	46-47
Application of Liquid Formulations	47-49
Compressed Air Sprayers	47-48
Hydraulic Sprayers	48
Air Blast Sprayers	48
Air-Liquid Mixing Chambers	48
Thermal Foggers	48-49
Rotating Cylinder or Disc Applicators	49
Aerosol Bombs	49
Biological Control	49-52
Mechanical Control	52
Integrated Control	52-53
Public Relations	53-55
ACKNOWLEDGEMENTS	56-57

LIST OF FIGURES

FIGURE		PAGE	SOURCE
Fig. 1.	Generalized diagram of a female mosquito	5	Mr. Ronald E. Schulze (after Carpenter et al.)
Fig. 2.	Sex differentiation of the adult mosquito	5	Medical Entomology; U.S. Naval Medical School
Fig. 3.	Generalized diagram of a larval mosquito	7	Mr. Ronald E. Schulze (after Carpenter et al.)
Fig. 4.	Anopheles larva	8	Headlee, T.J. 1945. The Mosquitoes of New Jersey and Their Control
Fig. 5.	Aedes larva	8	"
Fig. 6.	Culex larva	8	"
Fig. 7.	Mosquito eggs	9	Medical Entomology; U.S. Naval Medical School
Fig. 8.	Positions assumed by larvae of anopheline and culicine mosquitoes at the surface of the water	10	"
Fig. 9.	Pupa of mosquito at surface of water	11	"
Fig. 10.	Aedes canadensis	15	Headlee, T.J. 1945. The Mosquitoes of New Jersey and Their Control
Fig. 11.	Aedes vexans	16	"
Fig. 12.	Aedes sollicitans	17	"
Fig. 13.	Culiseta melanura	18	"
Fig. 14.	Coquillettidia perturbans	19	"
Fig. 15.	Culex pipiens	20	"
Fig. 16.	The New Jersey light trap	24	Mr. Ronald E. Schulze (after Carpenter et al.)
Fig. 17.	Landing count	25	" (original)
Fig. 18.	Killing tube and aspirator	26	" "
Fig. 19.	Pigeon baited trap	27	" "
Fig. 20.	Resting box	28	" "
Fig. 21.	Truck trap	29	" "
Fig. 22.	Dipping for mosquitoes	31	" "
Fig. 23.	Natural salt marsh pond with radial ditches	37	Dr. Terry L. Schulze
Fig. 24.	Natural salt marsh tidal creek with a lateral ditch	37	"
Fig. 25.	The mosquito fish, Gambusia affinis	50	Headlee, T.J. 1945. The Mosquitoes of New Jersey and Their Control
Fig. 26.	Natural predators of larval mosquitoes	51 - 52	"

INTRODUCTION

Insects and other animals which are involved in the transmission of diseases, cause discomfort by biting or stinging, and/or cause annoyance by their presence are considered economic and public health pests. In this respect, mosquitoes are one of the most important groups. In New Jersey, mosquitoes are known vectors of Eastern equine encephalitis, St. Louis encephalitis, and dog heartworm. Large numbers of these pests are the source of almost constant annoyance in many parts of the state. In areas where mosquito annoyance is great, agriculture is impeded, recreational areas become virtually unusable, and economic growth may be affected. Recent scientific studies resulting in technological advances have greatly reduced the mosquito problem in New Jersey, but the problem is still far from being eliminated.

Mosquitoes are unique in that they are the only pests whose control is mandated by state law. In New Jersey, the County Mosquito Extermination Commissions are the agencies responsible for controlling mosquitoes. Although the control methods used by these organizations are somewhat flexible, the County Mosquito Extermination Commissions must rely on technical information provided by the State Experiment Station. The State Experiment Station is charged by law to conduct research in order to provide these agencies with current, safe, and effective methods of control.

Considerable sums of money are invested annually in mosquito control in New Jersey, yet annoyance caused by these

pests continues to have a direct effect on the economy of the state. People do not wish to live in areas where mosquitoes interfere with normal living, and industry is not willing to accept the losses resulting from lowered efficiency of their employees. Mosquitoes often have the greatest effect on the resort industry where salt marsh species pose an all too frequent threat to the economy of many coastal towns.

In addition to the economic losses suffered as a result of annoyance, mosquitoes also threaten public health. Although malaria and yellow fever have been absent from New Jersey for some time, other mosquito-borne diseases remain a problem. Public health officials constantly look for and often find evidence of Eastern equine encephalitis and St. Louis encephalitis activity. Thousands of dogs die each year from dog heartworm, a mosquito-borne disease which has presently aroused considerable concern over possible human involvement. When the potential for mosquito-borne disease outbreaks is high, mosquito control becomes a priority activity.

Mosquitoes can be controlled by a number of methods. Source reduction through water management is the most widely used and ecologically sound approach to mosquito control. This method involves the many techniques for eliminating excess surface water and creating water circulation systems that allow natural predators access to the larval stages. Basic water management is almost always augmented by chemical control. Insecticide applications reduce peak populations of mosquitoes rapidly but do nothing to solve the basic problem. In emergency public health situations, the exclusive use of

insecticides will produce short-term control when a rapid reduction in numbers is necessary or desirable. However, where breeding occurs over large areas, the total reliance on insecticides for control would be ecologically unacceptable, quite costly, only temporary, and ultimately result in problems more serious than those being solved. Combining several control methods in an "integrated control" program will give the best results. Initially, this approach may take longer and be more expensive but eventually may prove less costly and less hazardous to man and the environment than a program based solely on the use of insecticides.

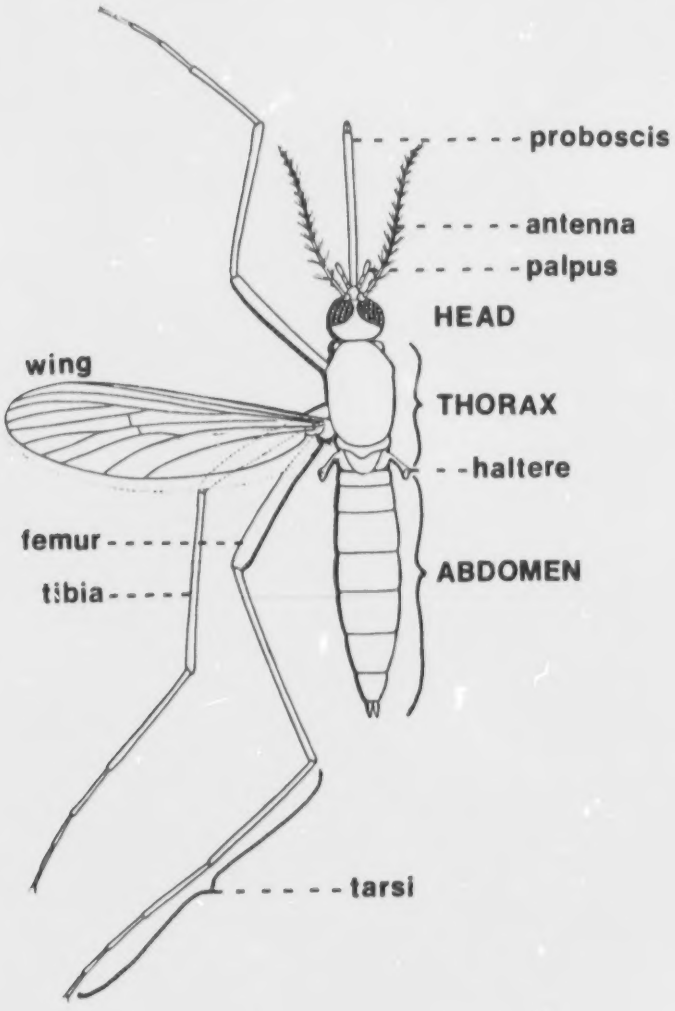
Essential to any mosquito control program is a thorough knowledge of the mosquito including its life cycle, habits, numbers, and location. With such information and an awareness of the alternate methods of control, mosquito control operations can more effectively attack the weak points in the mosquito's life cycle. Of course, such a broad-based approach to control is founded on an effective and informed program of surveillance that locates and defines problem areas. Before beginning a control program, consider consulting the responsible state and county mosquito control agencies for guidance and assistance.

IDENTIFICATION

Mosquitoes belong to the family Culicidae within the insect order Diptera. Like all true flies, they have only one pair of wings rather than the usual two pairs found in most other insects. Mosquitoes differ from other Diptera by 1. having numerous scales on the edges and veins of the wings and 2. by females having mouthparts extended into a long proboscis which contains needle-like stylets. These piercing-sucking mouthparts are suited for penetrating the skin of the host and sucking blood. All mosquitoes may be separated from other closely related insects such as midges and crane flies by these two characteristics.

Careful observation of mosquitoes will show that not all are the same size, shape, or color. Recognition of the differences between or the presence or absence of certain structures and markings (characters) is necessary for the identification of a particular mosquito. These characters may be arranged in a list or "key" so that by accepting or rejecting certain characters as they pertain to a specimen, one may narrow down the possibilities until the mosquito is identified. Mosquitoes sharing certain common characters are grouped into a genus and given a generic name such as Aedes or Culex. Further, mosquitoes which differ from one another within a genus may be separated to species. Species or specific names are binomial (made up of two words), for example, Aedes canadensis or Aedes vexans. Identifying mosquitoes to species is a difficult task and requires a microscope and considerable experience.

Fig. 1. Generalized diagram of a female mosquito



Since most adult mosquito keys apply only to females, the sex of the mosquito may be determined prior to identification attempts by examining the head. Male mosquitoes have bushy antennae and long palpi. Females have few bristles on their antennae and with the exception of Anopheles mosquitoes, have short palpi.

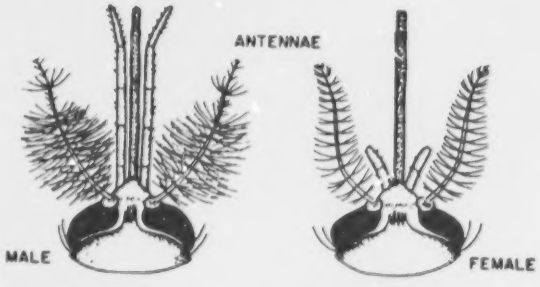


Fig. 2. Sex differentiation of the adult mosquito

Once this is accomplished, the next step in identification is determining the genus. The following is a key of the common mosquito genera of New Jersey.

KEY TO COMMON GENERA OF ADULT FEMALE MOSQUITOES OF NEW JERSEY

1. Palpi about as long as proboscis: Anopheles
   Palpi much shorter than proboscis: See #2

2. Abdomen blunt at tip: See #4
   Abdomen pointed at tip: See #3

3. Spiracular bristles absent; abdomen with pale scales usually at the base of some segments: Aedes
   Spiracular bristles present; abdomen with pale scales usually at apex of some segments: Psorophora

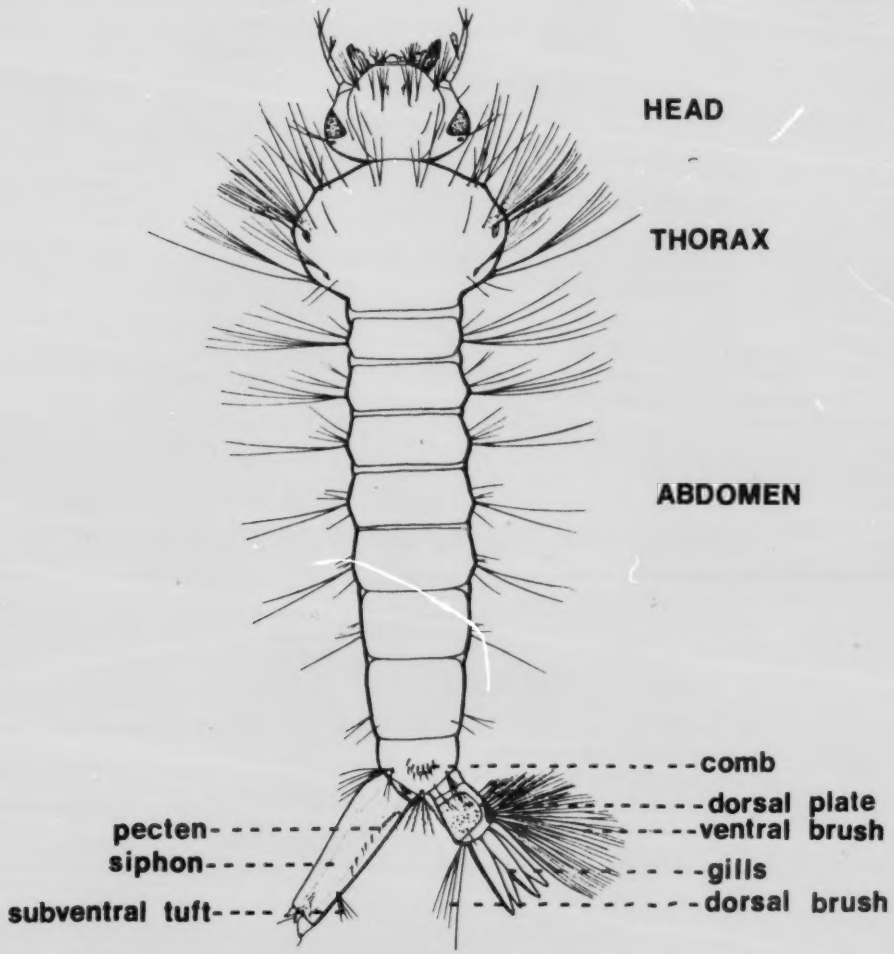
4. Wing scales narrow; majority of scales dark: See #5
   Wing scales broad; scales mixed dark and pale: Coquillettidia

5. Spiracular bristles present: Culiseta
   Spiracular bristles absent: Culex

Mosquito larvae may also be identified to genus and species but some experience is usually required for accurate identification. Knowing the location and appearance of

various structures and markings on the larvae is essential to proper identification.

Fig. 3. Generalized diagram of a larval mosquito



The larvae of the three most common genera may be separated by using the following key.

KEY TO THE MOST COMMON LARVAL MOSQUITOES OF NEW JERSEY

Larva with no air tube: Anopheles

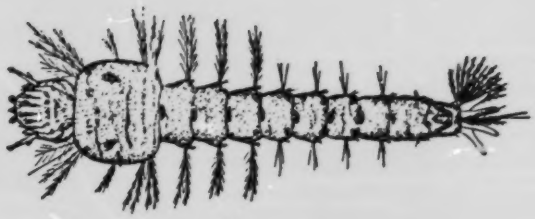


Fig. 4. Anopheles larva

Larva with relatively stout air tube; only one pair of tufts on air tube: Aedes

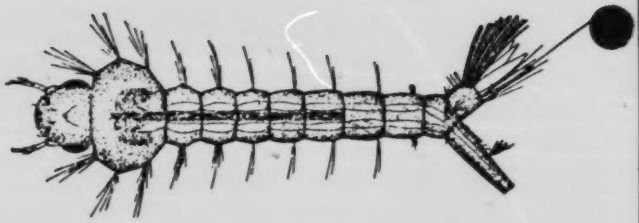


Fig. 5. Aedes larva

Larva with relatively slender air tube; several tufts or single hairs on air tube: Culex

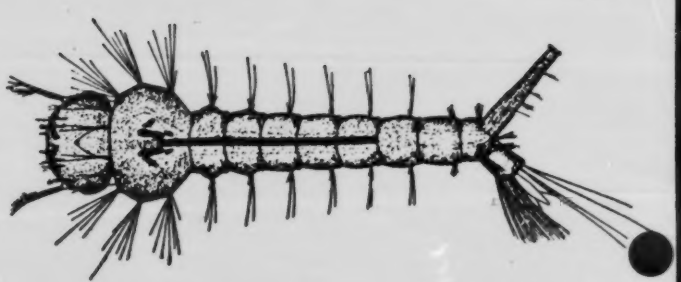


Fig. 6. Culex larva

MOSQUITO BIOLOGY

Mosquitoes, like all Diptera, undergo complete metamorphosis and thus develop through four life stages: egg, larva, pupa, and adult. Although the appearance of each stage may vary slightly according to species, the life cycle always follows the same basic pattern.

Eggs

The eggs of mosquitoes are normally black in color and barely visible to the naked eye. Although the specific shape of the eggs varies with the species, most are cylindrical or spindle-shaped. The majority of mosquitoes deposit their eggs singly, either directly on the water surface or on moist surfaces which will later flood. The eggs are heavier than water and usually remain submerged. These eggs are often able to withstand drying should the habitat dry down. Certain mosquitoes lay eggs with buoyant floats which enable the eggs to remain on the water surface. Other mosquitoes glue their eggs together to form a buoyant egg "raft" or "boat." Eggs which float upon the surface of

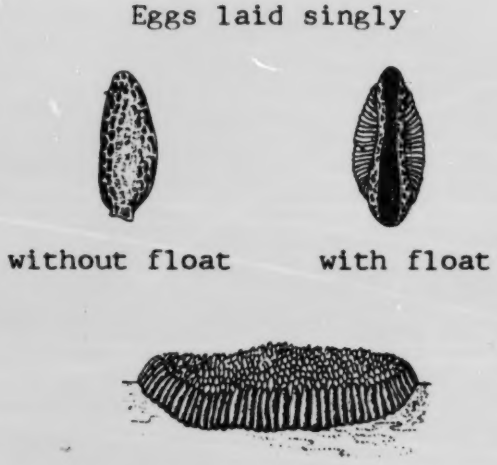


Fig. 7. Mosquito Eggs

the water are unable to withstand drying and perish should the habitat dry down. The various types of egg deposition are useful in identifying the particular groups or genera of mosquitoes.

Larvae

Mosquito eggs are usually ready to hatch within 3 to 10 days after oviposition. When conditions are suitable, the small larva breaks the shell and swims into the surrounding water. Without exception, the larval stage of the mosquito is totally aquatic. Although they live in water, most larvae must repeatedly return to the surface to obtain air. Most species possess an air tube or siphon on the tip of the abdomen which acts as a snorkle and enables them to breathe air while submerged. Anopheline mosquitoes do not have an air tube and must position themselves horizontally at the water surface in order to obtain air.

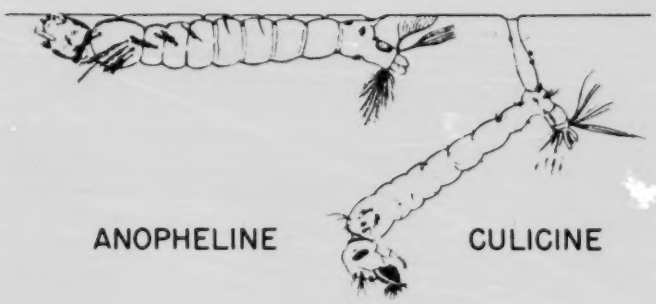


Fig. 8. Positions assumed by larvae of anopheline and culicine mosquitoes at the surface of the water

Mosquito larvae feed on a variety of small particles which are swept into their mouths by the action of a series of small brushes located near their mouths. Many species graze on the bottom, only returning to the surface to breathe. Mosquito larvae grow by a series of 4 molts where the entire skin is shed. After the 4th molt, the pupa appears. The period of time between molts varies and is largely dependent upon the quantity and quality of food and environmental conditions. Under optimum conditions, the 4th instar larva pupates within 7 days.

Pupae

Mosquito pupae are comma-shaped and have a pair of breathing tubes or "trumpets" near the head rather than a single, posterior siphon as in the larvae. Pupae do not feed but remain quite active and capable of rapid movement. Unless disturbed, this stage usually remains near the water surface. The pupal stage is relatively short and rarely lasts more than 4 to 5 days. During this time, the adult mosquito is forming within the pupal skin.

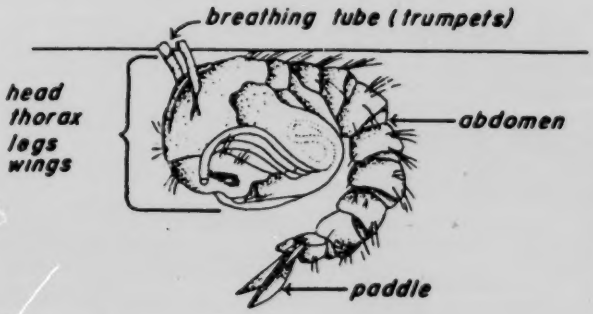


Fig. 9.
Pupa of mosquito at surface of water

When emergence time approaches, the pupa becomes less active. Within a short period of time, the pupal skin splits and the adult mosquito emerges, rests on the water surface until the skin hardens and the wings dry, and eventually

flies away.

Adults

The primary function of the adult is reproduction. Soon after emergence, the males search for mates. The antennae of the male mosquitoes are covered with sensitive hairs which enable the male to detect and locate the female by the vibrations of her wing beat. Locating potential mates requires considerable energy and adults feed at frequent intervals. Both males and females obtain this energy from plant juices and nectar.

Soon after mating, the female is ready to lay her first batch of eggs. The females of most mosquito species require blood for the production of eggs, but some species have eliminated this need for blood entirely. Males never feed on blood. The blood meal needed for egg production may be obtained from a variety of animals including man, and the female continually searches until a suitable host is found. Some species prefer to feed on one type of host while others feed on a number of different animals. When a suitable host is found, the female inserts her mouthparts beneath the host's skin until a blood capillary is located. The female then begins to feed and if left undisturbed, will feed until her abdomen swells with blood. She may feed at several locations on the same host or on different hosts until a full blood meal is obtained. After feeding, the female flies to a secluded place and digests the blood over a period of several days. When the eggs are fully developed, the female searches for a

suitable oviposition site. During her life, the female mosquito is capable of laying several batches of eggs. To produce each additional batch of eggs, she must seek and feed upon a host to obtain the necessary blood. It is this behavior of feeding on several hosts, that makes the mosquito such an effective vector.

Life Cycles and Larval Habitats

Although all mosquitoes require water to complete the larval portion of their life cycle, the species vary considerably with the quality of water present. Some species seek only the clean water found in freshwater swamps or woodland pools, while others breed in brackish salt marshes or the polluted water left standing in old tin cans and tires. Fifty-five mosquito species are known to breed in New Jersey and virtually every conceivable water source fulfills the breeding requirements of at least one species.

The type of water used by the female mosquito for breeding is referred to as the larval habitat. In many instances, the larval habitat has a direct bearing on the life cycle of the particular species of mosquito including the time of year that a mosquito is active and the number of generations that are produced during a season.

Since most control procedures are directed against the larval stages, mosquito control workers should be able to associate the pest species with its larval habitat. Initiating control procedures on a freshwater swamp will not eliminate a nuisance problem, for example, if the mosquitoes are

breeding elsewhere.

Mosquito larval habitats may be divided into two very broad categories, temporary pools which only flood for brief periods and semi-permanent water sources which remain flooded for most of the season. Each type can be further subdivided into the most important larval habitats as follows:

TEMPORARY POOLS

1. Woodland pools
2. Floodwater (fresh)
3. Salt marsh pools

SEMI-PERMANENT WATER

1. Freshwater swamps and marshes
2. Polluted water
3. Street catch basins and various containers

Woodland Pool Mosquitoes

Woodland pool mosquitoes breed in standing water which has collected in depressions during early spring. Examples include the woodland depressions which are filled with water from melting snow as well as the roadside ditches that collect runoff water. The woodland pool mosquitoes generally have only one generation per year. Eggs are deposited on the moist soil surrounding depressions during the late spring or early summer as the pools begin to dry down. The eggs remain in a dry condition for much of the summer. If summer and fall rains flood the depressions, the eggs will not hatch. The eggs survive the winter months covered with leaves and mud

beneath the ice. Hatching takes place the following spring when the ice and snow begin to melt. The larvae develop in relatively cold water early in the season. By late April or early May, the adults emerge and the females begin to seek blood meals. Woodland pool mosquitoes are early season pests and are most numerous during May and June. By mid-summer, most of the adults have died off and will not be seen again until the following year when the eggs develop and hatch.

The most important woodland pool mosquito in New Jersey is Aedes canadensis. The larvae are particularly abundant in April and May and adult females can be extremely annoying in woodland areas late in the spring. Unlike most of the other woodland pool mosquitoes, the larvae and adults of Aedes canadensis may occasionally be found later in the year.

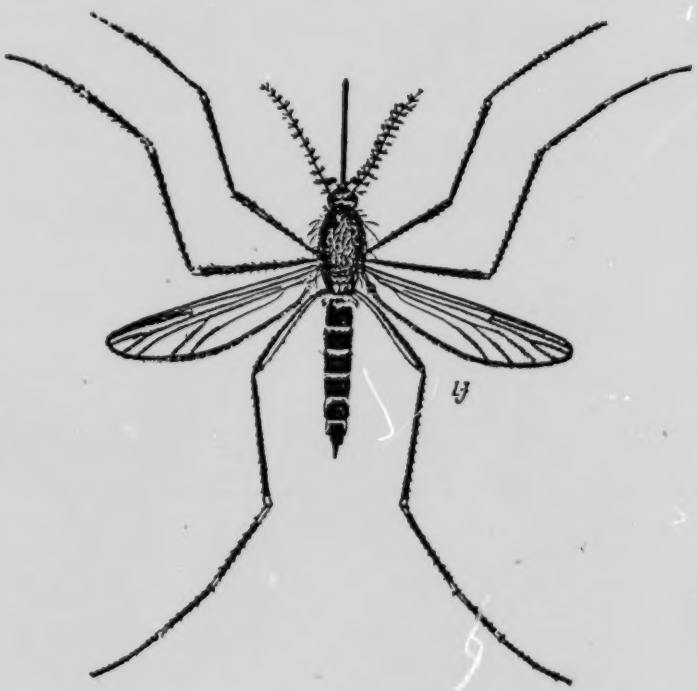


Fig. 10. Aedes canadensis

Floodwater Mosquitoes

Floodwater mosquitoes breed in collections of standing water and may have several broods per year. Some pools are filled directly by rainwater, while others are filled with water which has overflowed from rivers and streams. The females deposit their eggs in depressions as they are drying down. Like those of the woodland pool species, the eggs of floodwater mosquitoes can remain in a dry condition for long periods of time, but hatch as soon as they are covered by water. A fresh brood of biting adults may then appear shortly after each flooding during the summer. Thus, these pests will appear and disappear at varying intervals throughout the season. In the fall, the adults die off and the next generation overwinters in the egg stage.

The most important floodwater mosquito in New Jersey is the swamp mosquito, Aedes vexans. In years of heavy rainfall, the adults cause annoyance all summer long. Because each rain can trigger the hatching of a separate batch of eggs, this species requires repeated control throughout the season.

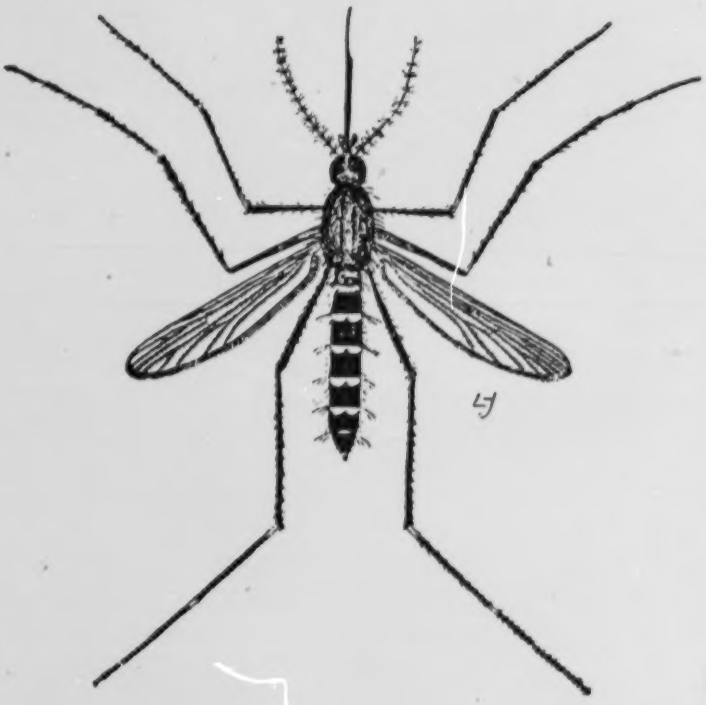


Fig. 11. Aedes vexans

Salt Marsh Mosquitoes

Salt marsh mosquitoes breed in standing water which collects in depressions on coastal marshes after a heavy rain or an exceptionally high tide. The larvae are able to tolerate the high levels of salt which are found in the pools as the water evaporates. Populations of salt marsh mosquitoes appear and disappear at regular intervals during the summer and their presence is directly related to the tidal flooding of the marshes. In most parts of the state, there are four or more major floodings during the breeding season. Because of the large acreage of breeding habitat involved, salt marsh mosquitoes can emerge in unbelievably high numbers. Most species are strong fliers and will travel many miles to locate a suitable host. The salt marsh mosquitoes directly affect

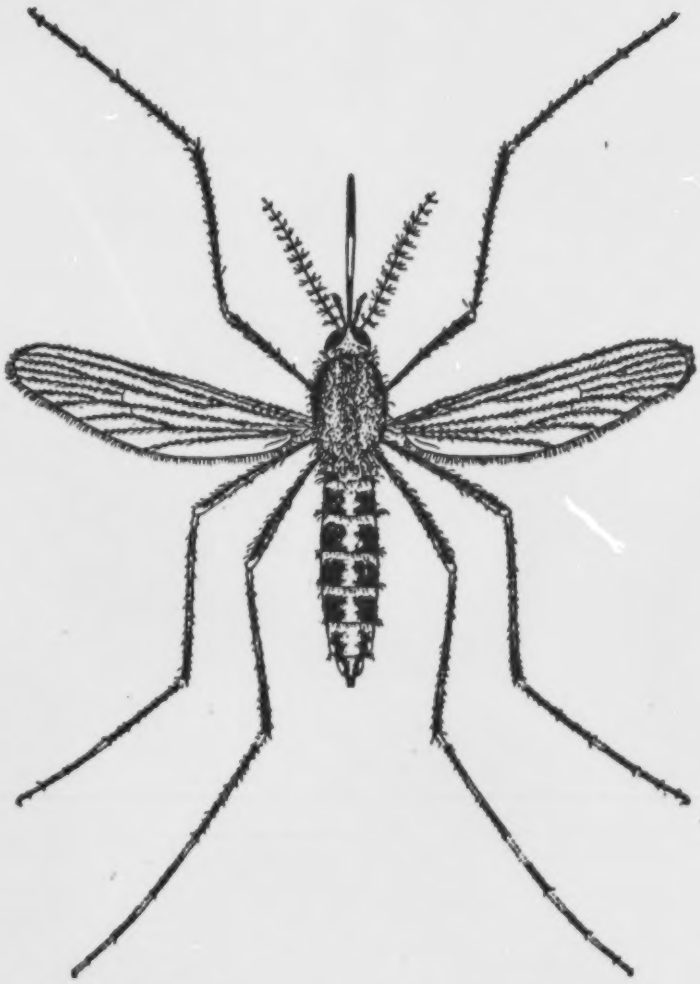


Fig. 12. Aedes sollicitans

the economy of New Jersey's coastal resorts.

The most important salt marsh mosquito in New Jersey is Aedes sollicitans. This mosquito bites throughout the daylight hours and is a constant source of annoyance from late spring to late fall.

Freshwater Swamp Mosquitoes

Freshwater swamp mosquitoes breed in semi-permanent water such as swamps, bogs, or freshwater marshes. Most species are associated with some form of aquatic vegetation. The eggs of freshwater swamp mosquitoes float on the water surface and cannot withstand drying. Consequently, they always hatch within several days. Eggs are deposited throughout the breeding season. Thus, freshwater swamp species are present at all times during the summer and do not appear and disappear as do the temporary water breeders.

Some of the freshwater swamp mosquitoes hibernate as adults during the winter months. With the approach of spring,

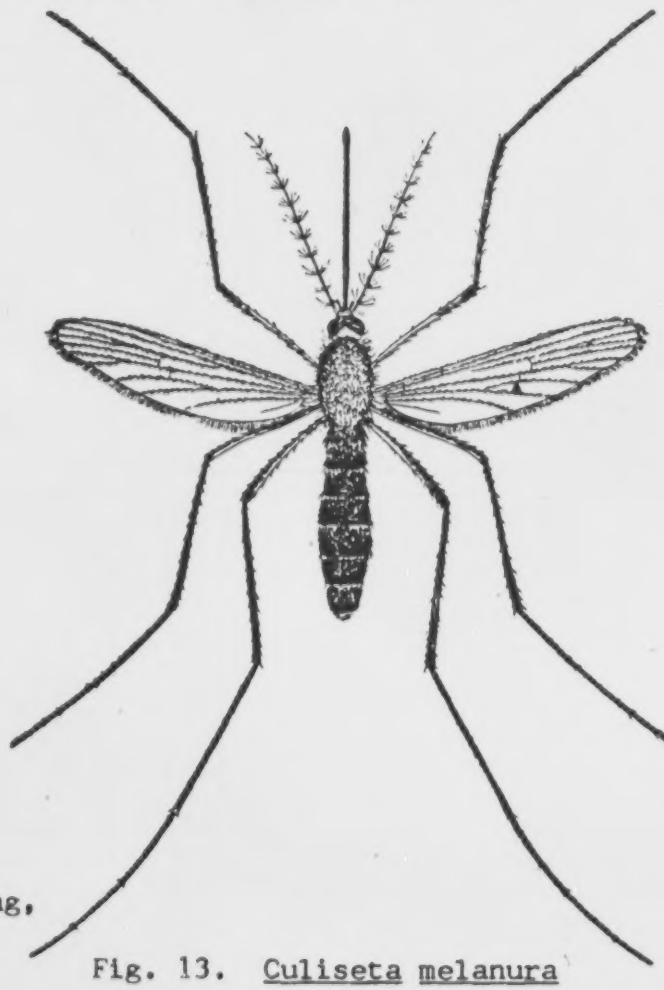


Fig. 13. Culiseta melanura

the adults become active and begin to lay eggs.

The most important freshwater mosquito in New Jersey is the black tailed mosquito, Culiseta melanura. This mosquito breeds in acid cedar bogs in many parts of the state. Culiseta melanura does not bite man but transmits Eastern equine encepalitis viruses from bird to bird which other mosquitoes may then transfer to man.

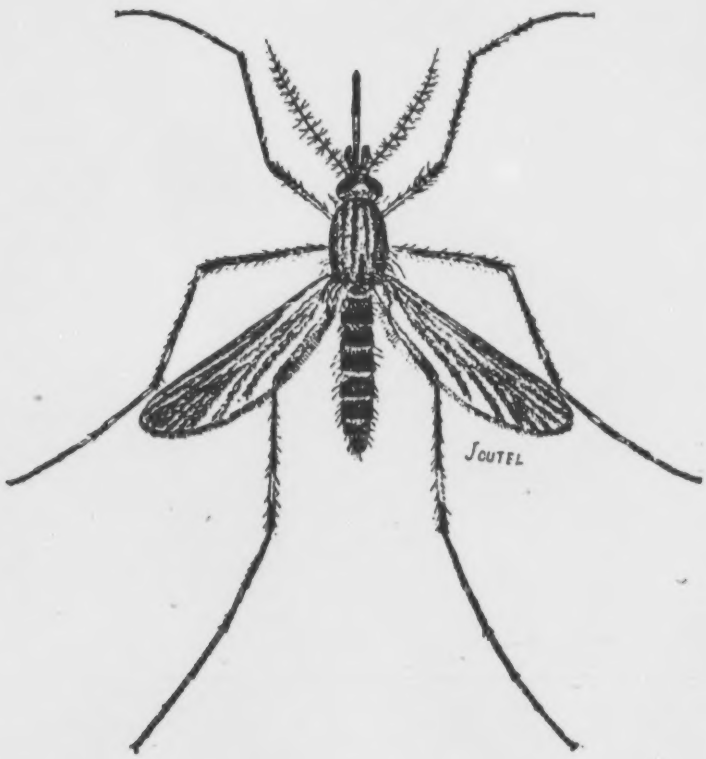


Fig. 14. Coquillettidia perturbans

Another important freshwater swamp mosquito is the irritating mosquito, Coquillettidia perturbans. The larvae of this mosquito have pointed air tubes which are inserted into the roots of some aquatic plants. Air is obtained directly from the plant, and the larvae never come to the water surface. Swamps with stands of cattails often support large populations of this species. The females are severe biters and cause considerable annoyance in some areas of the state.

Polluted Water Mosquitoes

Some mosquitoes are able to breed in water with a high

level of organic pollution. Sewage seepage, effluent from industry, and discarded tin cans and tires filled with water provide these mosquitoes with a suitable larval habitat. In most cases, the behavior of these mosquitoes is similar to that of the freshwater swamp group. The eggs float on the water surface; egg laying is constant throughout the breeding season and the adults spend the winter in hibernation. Mosquitoes which utilize polluted water, however, are usually associated with man and are most numerous in and around cities and towns.

The most important polluted water species in New Jersey is the house mosquito, Culex pipiens. It will breed in any water which is stagnant. Many homeowners unknowingly provide this mosquito with a choice of suitable breeding sites such as clogged rain gutters, tires, tin cans, and wading pools. As a result, breeding may occur around the home throughout the summer.

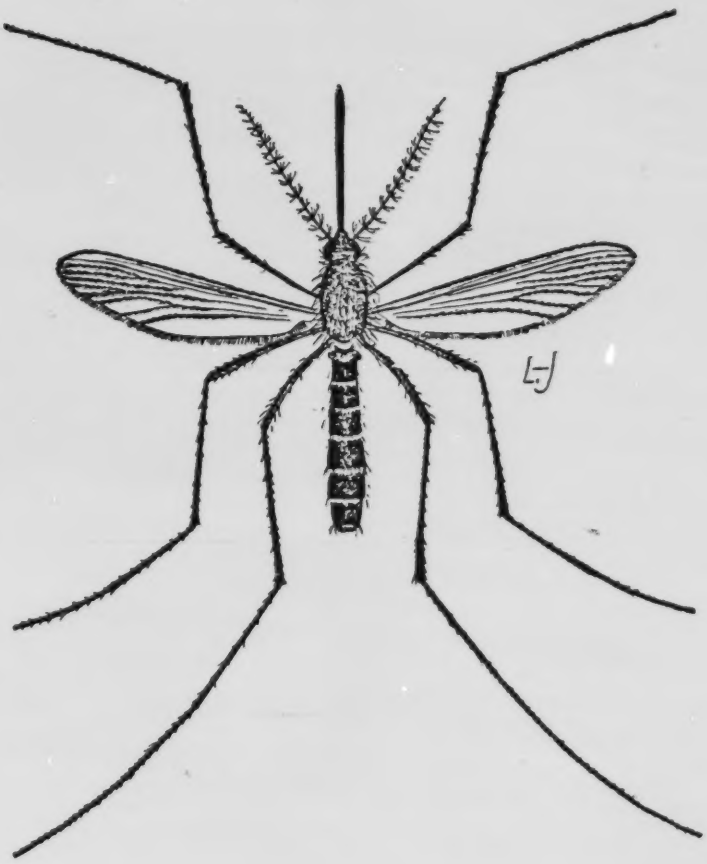


Fig. 15. Culex pipiens

MOSQUITOES AS VECTORS OF DISEASE

During the summer months, individual mosquitoes may lay as many as four batches of eggs before dying. To produce each of these egg batches, the females require a separate blood meal. Thus, the mosquito feeds on blood at variously spaced intervals during her lifetime. Many disease organisms are carried in the blood of man and other animals in nature. This multiple feeding behavior of mosquitoes gives them the ability to transmit these parasitic organisms from one animal to another, making the mosquito an ideal disease vector.

If the mosquito acquires its first blood meal from an animal that is carrying disease organisms, the contaminated blood serves as a source of infection. While the mosquito digests the blood and develops her eggs, the parasites multiply or develop within her body. By the time she is ready to feed again, the parasites are ready to be transmitted.

Mosquitoes which are newly emerged do not present an immediate health hazard as they have never fed on blood and thus, have not yet obtained disease organisms. It is the older mosquito which has taken one or more blood meals that can function as a vector.

Malaria and yellow fever are the most important mosquito-borne diseases of man in the world today. Fortunately, both these diseases rarely occur in the United States. Other mosquito-borne diseases, however, are present and do pose a threat to the health of man and his animals. Humans and animals can contract mosquito-borne encephalitis and dog heart-

worm kills thousands of dogs every year.

Mosquito-borne Encephalitides

Eastern Equine Encephalitis

Eastern equine encephalitis (EEE) is another viral disease that can be transmitted by mosquitoes. Wild birds serve as the reservoir of the virus. The disease occurs along the eastern coast of the United States and is particularly prevalent in the southern portion of New Jersey. The virus is more severe for humans than St. Louis encephalitis and frequently results in death. Eastern equine encephalitis also occurs in horses and pheasants. Horse breeders and pheasant raisers in New Jersey must vaccinate their animals or face the possibility of tremendous economic losses.

Culiseta melanura is known to transmit the virus in wild birds. Aedes sollicitans and Aedes vexans are suspected of being the major vectors of the disease in human and horse cases.

St. Louis Encephalitis

St. Louis encephalitis (SLE) is a viral disease which is transmitted to humans by the common house mosquito, Culex pipiens. This virus occurs naturally in wild birds in many parts of the United States including New Jersey. Affected humans develop severe headaches and fever. In extreme cases, brain damage or death can result from the infection.

Since Culex pipiens is primarily an urban mosquito, most outbreaks of St. Louis encephalitis occur in and around cities and towns. More than 100 human cases of St. Louis

have occurred in New Jersey in the last ten years.

Dog Heartworm

Dog heartworm is another mosquito-borne disease which directly affects the economy of the state. The disease annually takes the lives of many of our pets, and there is currently some concern over the possibility of human involvement. The parasite is a long, thread-like worm which invades the heart of an infected dog and eventually kills the animal if the condition remains untreated. Most dog owners are not aware that their pet is infected. The disease is most common in outdoor breeds but veterinary records clearly show a high incidence in house dogs as well. Preventative medication is available.

The natural vectors of dog heartworm are still unknown in most areas. In all probability, a number of different mosquito species transmit the infection during the summer months.

SURVEY METHODS

One of the most important elements of a successful control program is surveillance. Surveillance is the detection of the mosquito problems, the species involved, their numbers, and location. The information provided by surveillance programs and a thorough knowledge of the mosquito's biology, habits, and habitats will provide a sound basis for control. Besides providing the immediate information on whether the particular problem warrants control and the methods of control to be employed, analysis of these data on a long-term

basis will furnish a continuous evaluation of control efforts.

Adult Mosquito Surveillance

Adult mosquito surveillance provides data on the presence of various species, their relative abundance, and location at any given time. These data are essential in determining the specific location and optimal timing of a control program. Further, this information should lead to the successful search for larval breeding areas and control of the larvae.

A description of the various methods of adult surveillance and their limitations follow.

The New Jersey Light Trap

The N. J. light trap is probably the most common device used in detecting the presence of adult mosquitoes. The trap consists of a 16-inch long, 9-inch diameter cylinder with a conical roof mounted 2 inches above the cylinder. The inside surface of the roof is painted white and holds a 25 watt white bulb which acts as the source of attraction. As the mosquitoes

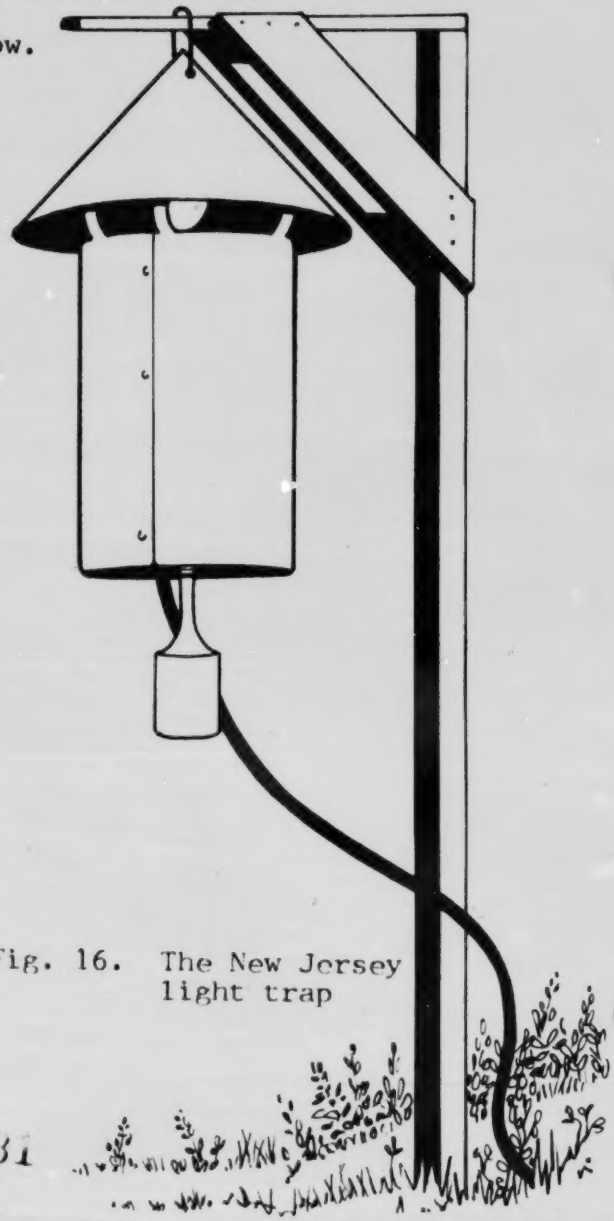


Fig. 16. The New Jersey light trap

are attracted to the light, a fan draws the insects into a killing jar attached to the bottom of the cylinder. Since light is the source of attraction, both males and females are surveyed by this method. This trap also attracts and captures other insects which may damage the trapped mosquitoes and make identification more difficult.

Landing Counts

Mosquitoes which come in to land on or bite a human host during a given period of time, may be counted and/or captured in a survey method known as landing counts. The person conducting the landing count usually walks into the survey area to disturb the mosquitoes. After waiting about a minute, the individual counts the number of mosquitoes landing on his/her arms or legs for a predetermined interval. Depending on mosquito abundance, this interval may be 1, 5, or 10 minutes in length. Regardless of the method or time interval used, the same procedure should always be followed so that comparisons between counts can be made.

Fig. 17. Landing count

When surveying mosquitoes for vector potential or for further identification, the mosquitoes which land may be captured with a killing tube or an aspirator. A killing tube is merely a tube or vial whose bottom inch is filled with a killing agent such as ethyl acetate and covered with cotton. When the mosquito lands, the killing tube is placed over the mosquito until it dies. When mosquito populations are high, capturing specimens with an aspirator is a quicker and more effective method than using a killing tube. An aspirator consists of a 12-inch long, ½-inch diameter tube with a siphon hose attached to one end. A screen is fitted between the tube and the hose to prevent inhalation of the specimens. Mosquitoes are drawn into the aspirator as the collector draws

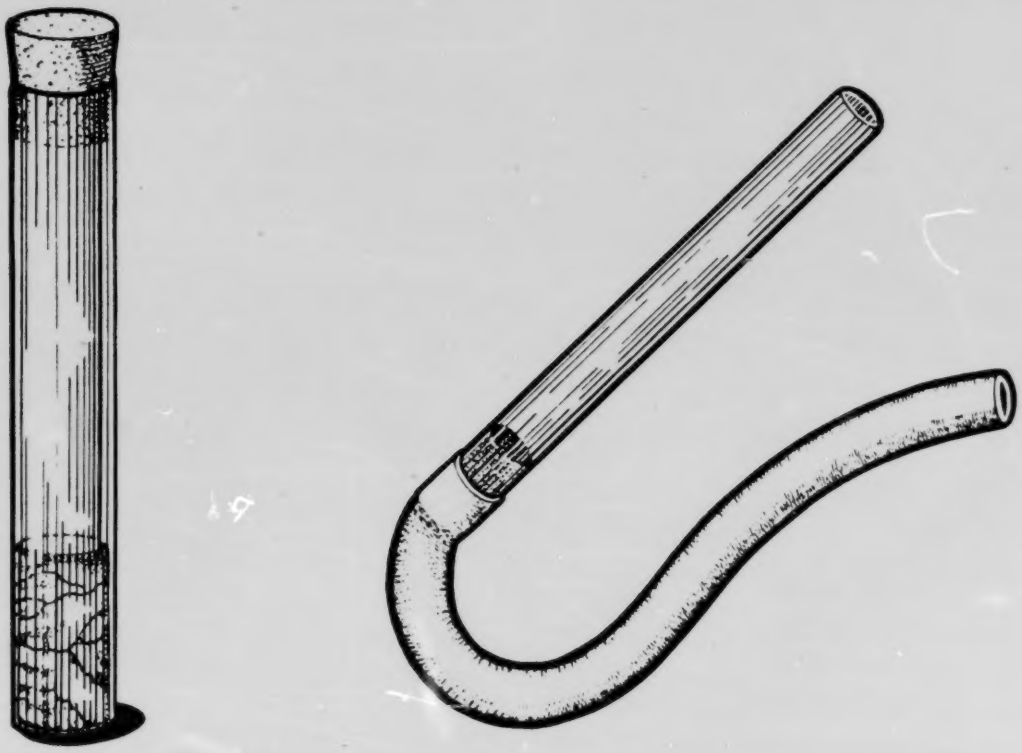


Fig. 18. Killing tube and aspirator 33

air through the hose. Specimens are then transferred to a killing tube for further identification. The landing count method samples that portion of the female mosquito population which is seeking blood.

Pigeon Baited Traps

Pigeon baited traps consist of a 24-inch long, 12-inch diameter metal cylinder. A pigeon is housed in the center of the trap and mosquitoes attempting to feed are automatically trapped in screen cages located at both ends. These traps are normally suspended from poles at a height of 5 to 6 feet above the ground.

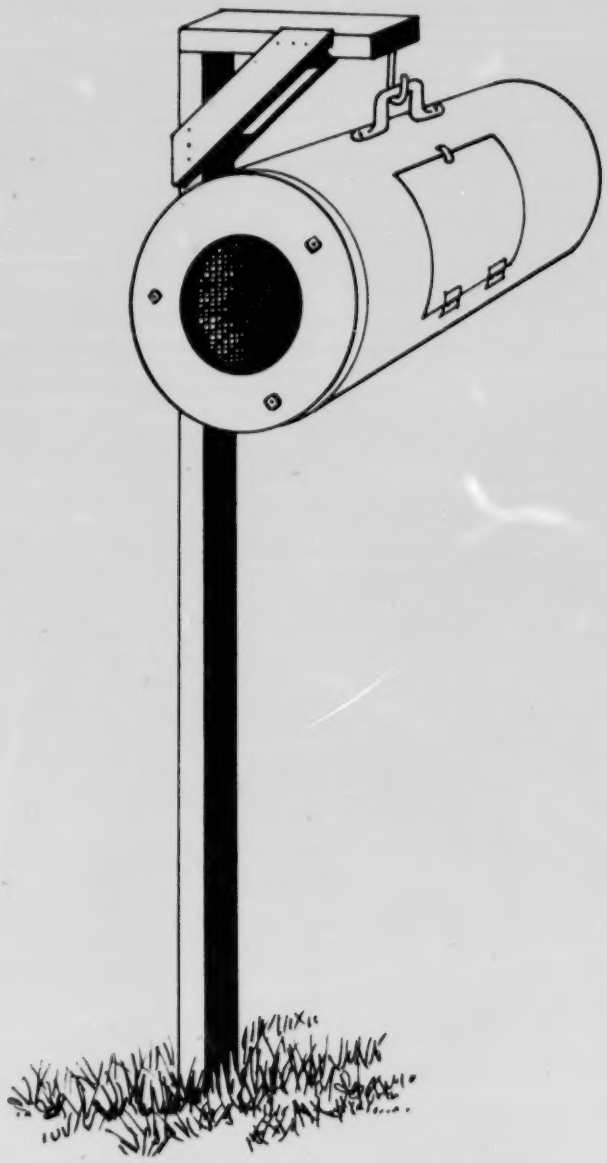


Fig. 19. Pigeon baited trap

Pigeon baited traps also sample the blood-seeking segment of the mosquito population, but a pigeon serves as the bait rather than the

human as in the landing count method. Since birds act as natural reservoirs for encephalitis, this method is commonly used in vector surveillance. Mosquitoes which are exclusively mammalian feeders will normally not be trapped by this method.

Resting Boxes

Resting boxes are 12-inch cubes which are open at one end. The interior of the boxes is usually painted red while the exterior is black. They are usually placed in groups of four (10 to 20 feet apart) in vegetation near suspected breeding sites. Although both sexes may be surveyed, females which have recently fed on blood and need a dark, secluded place to digest the blood meal are most commonly taken by this method. Mosquitoes may be taken alive and later examined for the presence of disease organisms.

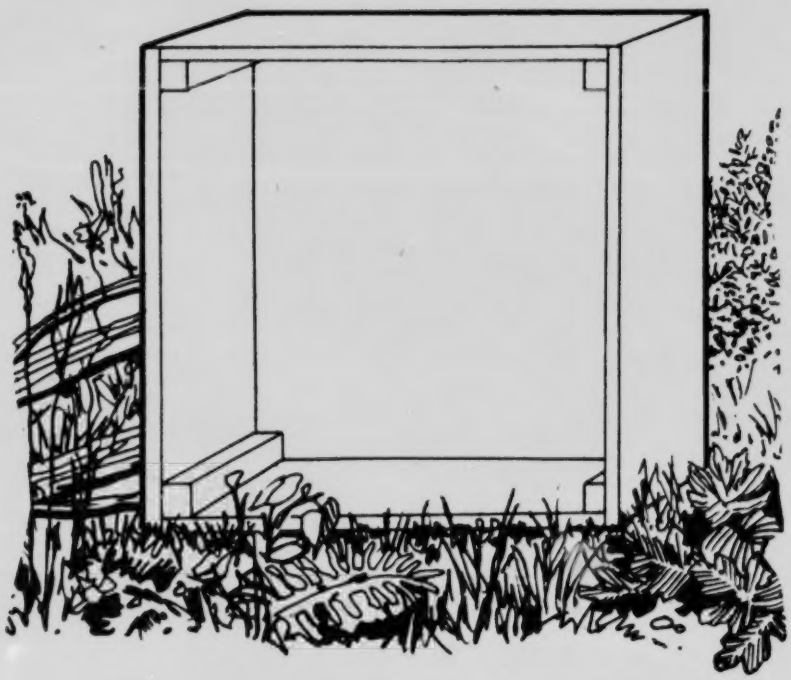


Fig. 20. Resting box

Truck Traps

Truck traps consist of a large, rigid, tapered, screened funnel which is mounted on top of a vehicle. The dimensions of the funnel mouth are usually 2 feet high by 6 feet long. Mosquitoes are intercepted and forced into a net bag at the rear of the funnel by the forward motion of the vehicle. Normally, the vehicle is driven at 15 mph. This survey method differs from all other methods in that the sample is taken over an extended distance and is not selective with regard to sex or whether or not the female is seeking blood. Truck traps, however, do select those species which tend to fly at the altitude of the traps, those which fly in open areas such as

Fig. 21. Truck trap

roads, and those which fly at a certain time of day.

Listed below are the more economically and medically important mosquito species and the adult surveillance methods most commonly used to collect them.

SPECIES	TYPE OF SURVEILLANCE METHOD (in order of effectiveness)
1. Aedes canadensis	Landing counts, New Jersey light traps
2. Aedes vexans	New Jersey light traps, landing counts
3. Aedes sollicitans	Landing counts, New Jersey light traps, truck traps
4. Culiseta melanura	New Jersey light traps, resting boxes
5. Coquillettidia perturbans	New Jersey light traps, landing counts, pigeon baited traps
6. Culex pipiens	Pigeon baited traps, New Jersey light traps, landing counts

Larval Mosquito Surveillance

The survey of mosquito larvae indicates sites, species involved, and whether sufficient numbers are present to warrant control. If adult surveillance reveals a large population of one species, it is also essential to know the biology, habits, and habitats of the larvae so that the breeding sites may be more easily located.

The equipment needed to survey the larvae is minimal and includes a 1-pint dipper with an extended handle used to sample water for larvae and a container to transport the larvae to the laboratory. A microscope may be necessary for accurate identification.

It is necessary to proceed slowly and carefully in searching for mosquito larvae as disturbance of the water or casting shadows may cause the larvae to swim to the bottom. The dipper is carefully depressed in the water near vegetation or debris so that the water gently flows into it. The stroke is ended just before the dipper is filled with water. The number of dips taken and the number of larvae found per dip should be recorded.

Fig. 22. Dipping for mosquitoes

The more common and important mosquito species and their larval habitats are listed below.

SPECIES	LARVAL HABITAT
1. Aedes canadensis	Woodland pools and woodland swamps whose bottoms are covered with dead leaves
2. Aedes vexans	Almost all bodies of fresh water which result from flooding
3. Aedes sollicitans	Salt marshes which are not generally covered by daily tides but are flooded by abnormally high tides or heavy rains
4. Culiseta melanura	Woodland and cedar swamps under the root systems of trees
5. Culex pipiens	Quiet water of almost all types, from artificial containers to to large bodies of permanent water, especially water with a high organic content
6. Coquillettidia perturbans	Ponds, lakes, and marshes having a thick growth of emergent aquatic vegetation

With the exception of Coquillettidia perturbans, the larvae of the previously mentioned species may be sampled with a dipper. The larvae of Cq. perturbans, however, are rarely free swimming and breathe by inserting their pointed air tubes into the roots of aquatic plants. These larvae are best sampled in the winter when temperatures are low and the larvae are less active. The procedure involves uprooting aquatic plants and placing them in a pail of clean water where they are then vigorously shaken. The resulting debris is poured

through a 16-mesh screen partially submerged in water. Gentle agitation removes the fine sediment, leaving the coarser debris and larvae in the screen. By moving the screen up and down in a pan of clean water, the larvae can be located and removed.

Records

Accurate records of larval and adult mosquito populations are essential. Records will indicate changes in mosquito population levels and allow comparisons of mosquito abundance after various control programs have been conducted. Records kept on a long-term basis will facilitate decision making on control methods needed. Specific information should include date, species, location, description of the area, density of breeding, weather conditions such as rainfall and temperature, and control procedures used. It is especially important to keep precise records of insecticide usage.

CONTROL

As mentioned earlier, the total reliance on insecticides for mosquito control is seldom the best approach. The use of water management, biological control, and mechanical control or a combination of these methods (including chemicals) in an "integrated control" program often gives the better results in the long run. Always weigh the effectiveness, possible environmental hazards, cost, and other factors before selecting a particular method or methods of control.

Water Management

Water management is the cornerstone of mosquito control in New Jersey. Water management involves the alteration of the land surface, drainage ways, or ponds and lakes in order to eliminate excess surface water which may serve as mosquito breeding habitats. Water management should be especially considered when a mosquito problem area requires many chemical treatments each year. Although the initial cost of water management may be higher, it may prove less expensive in the long run than repeated insecticide applications.

The control of mosquito populations by the use of water management techniques is directed toward the aquatic stages. The three basic principles involved in water management are:

1. the removal of excess surface water within 5 days thereby eliminating the mosquito breeding habitat.
2. increasing the amount of standing water to create a suitable habitat for predaceous fish and/or constructing means of access for these fish into and out of breeding areas.
3. increasing the movement of water in the mosquito breeding area and thus creating stress conditions for the larval and pupal mosquitoes.

Although these three principles may be applied to all types of water management methods, the ecosystem in which they are to be used should receive primary consideration. Habitats which are necessary for the production of wildlife such as waterfowl and other birds, land animals, and fish, as well as their food sources, must be preserved.

Freshwater

The general maintenance of existing drainage ditches, streams, and rivers is essential in any upland water management program. The elimination of debris that normally accumulates in these water courses is necessary to prevent the possible creation of habitats associated with mosquito breeding.

Restoration of some rivers, streams, and ponds is important in maintaining a system that is free of mosquitoes. Many rivers and streams have a flood plain which may accumulate standing water after a heavy rain thereby providing suitable mosquito breeding habitats. Successful restoration projects involve the removal of any excess surface water by providing outlets to and for tributary streams. Restoration of ponds usually entails the removal of aquatic vegetation and/or the excavation of silt to a depth that will maintain an adequate population of fish and other mosquito predators.

Another source reduction technique involves the filling in or grading of mosquito breeding areas. Landfills function similarly on a larger scale. The removal of standing water from cans, bottles, tires, and wrecked automobiles such as found in junkyards or preventing such situations, may substantially reduce mosquito populations. Around dwellings, mosquitoes may be reduced by periodically removing the water from birdbaths, wading pools, or other receptacles which may hold water.

Saltwater

Ditching of coastal salt marshes has elicited the concern

of many ecologists and environmental groups. In the past, water management consisted of the construction of parallel ditches throughout a particular section of the marsh. In some instances, the creation of jobs in the early 1930's was as much of a consideration as mosquito control. In New Jersey, however, this practice has long been abandoned and new procedures developed to the point where New Jersey is considered by many as a leader in water management methods. New techniques have been developed as a cooperative effort between various fish and wildlife agencies and mosquito control agencies. These methods are designed to complement each component of the salt marsh-estuarine ecosystem while controlling mosquitoes.

The water management technique used largely depends on the extent and location of mosquito breeding areas. Basically, ditching, ponding, and impounding are the three types of water management practices used in coastal areas.

Ditching- Ditching refers to the practice of connecting a series of mosquito breeding depressions with a larger, more permanent body of water. They may be constructed radially from a natural salt marsh pond or from a tidal creek. The purpose of this practice is two-fold: (1) to reduce or completely drain the standing water from the depressions at a low tide and/or (2) to allow access of predaceous fish into the breeding depressions at higher tides. Many of these ditches also create habitats for the food sources of many waterfowl and shore birds.

Fig. 23. Natural salt marsh pond with radial ditches

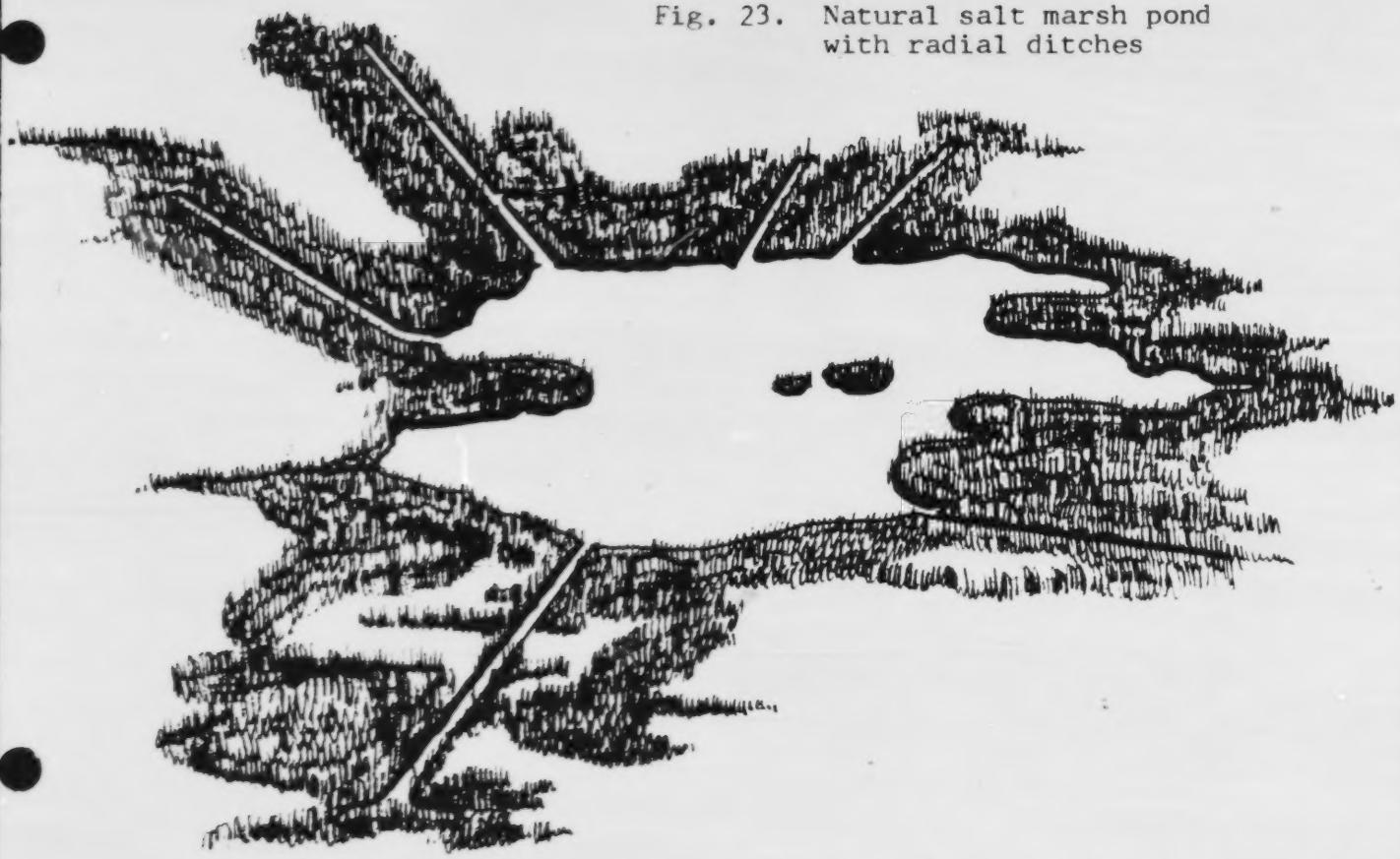
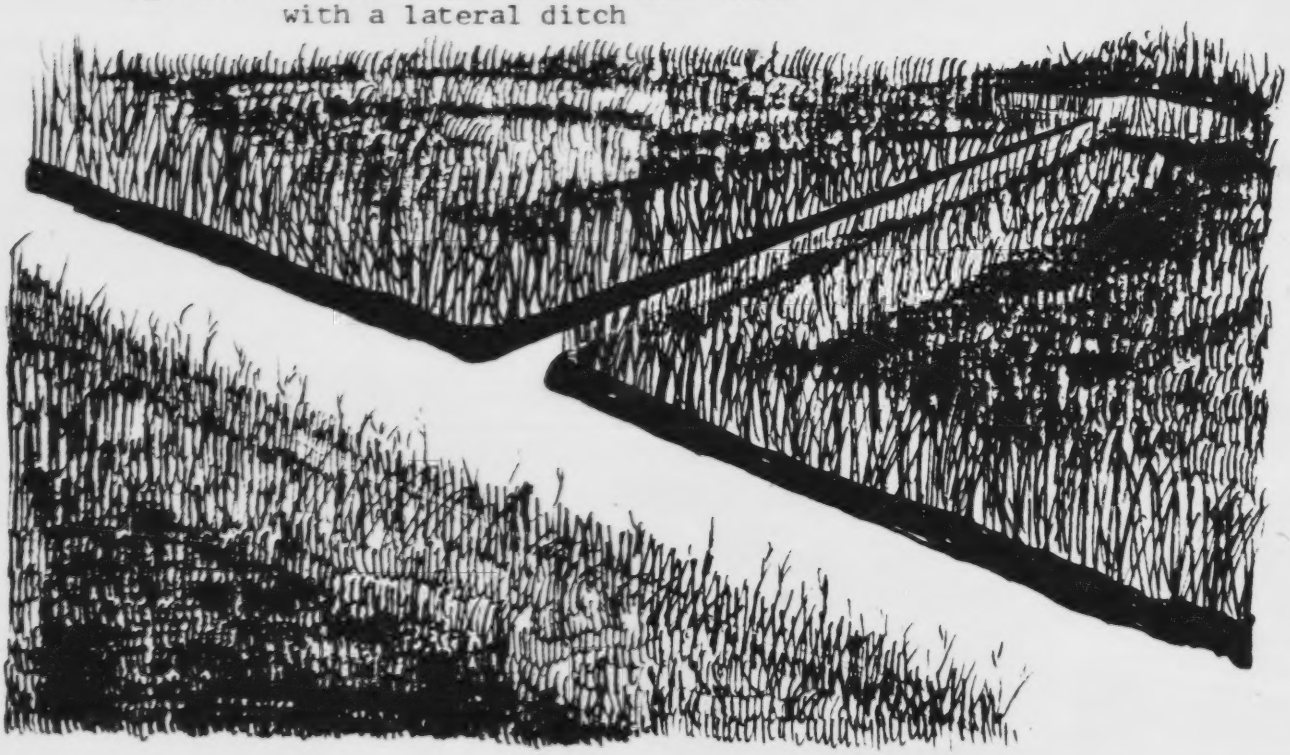


Fig. 24. Natural salt marsh tidal creek with a lateral ditch



Ponding- When many depressions are located within a more or less defined area, the best approach may be ponding. Here, a shallow pond is constructed which encompasses all the breeding depressions. During extremely high tides, predaceous fish are often introduced into the pond. To accommodate these fish during dry spells, the perimeter of many ponds are constructed several feet deep. Square or rectangular ponds are easier to construct, but naturally shaped ponds may be constructed to enhance their appearance. As with natural ponds, radial ditches may be constructed to connect nearby breeding depressions. These ponds have also been shown to be an ideal habitat for local and migratory waterfowl as well as a food source for many other organisms.

Impounding- Impoundments may be constructed when large concentrations of breeding depressions occur over an extensive area. In such instances, ditching or ponding would be impractical. Like ponds, impoundments are designed to create bodies of standing water sufficient to support fish and other mosquito predators while eliminating the breeding habitats of Aedes mosquitoes. The water, which is held behind low level dikes, may originate from freshwater upland sources or saltwater resulting from spring or storm tides. Water levels may be manipulated by water control structures built within the impoundment. Variations in water levels can control undesirable vegetation while enhancing the utilization of the impoundment for waterfowl and muskrats.

Water management programs are costly and require the

accumulation of sufficient data to make a judgement on the best method to use so as to minimize any adverse effects on the environment or whether water management is indeed the best approach. The physical alterations of ground topography that accompany many water management methods require extensive planning and are strictly regulated by various federal and state agencies. The necessary permits must be obtained before a water management project is begun.

Chemical Control

Insecticides

There are a number of insecticides which have been used to control mosquitoes. These chemicals may be grouped according to the stage of mosquito against which they are used, e.g., adulticides kill adult mosquitoes and larvicides kill larvae. Certain insecticides may be more effective against only one stage of the mosquito while others, by altering their formulation, concentration, and/or method of application, may be effective against several stages. Secondly, insecticides may be classified according to their mode of action, that is, killing by contact or by ingestion. The third, and perhaps more useful way to group insecticides, is according to their chemical family or type.

The two basic types of insecticides are inorganic and organic.

Type 1. Inorganic Insecticides. The inorganic insecticides are those which generally do not contain carbon. The best known example of this type used in mosquito control is

the arsenical, Paris Green. These insecticides are stomach poisons and as such, must be eaten by the mosquito larvae to be effective. Thus, the particles of the insecticide must be small enough to be picked up and swallowed by the larvae. Since the pupae never feed and the adults feed only on liquids, the arsenicals are not effective against these stages and have been used exclusively as larvicides. However, this type of insecticide is no longer recommended for use in New Jersey.

Type 2. Organic Insecticides. The organic insecticides are numerous and will be separated into smaller groups for discussion.

Group 1. Oils. This group contains materials which are sprayed on water. They act as both larvicides and pupicides. These oils may be partially refined products like Fuel Oil #2 or more highly refined ones like Flit MLO. These materials act by suffocating the larvae or pupae or by poisoning them as they take in toxic vapors through their breathing tubes. Because of their different physical characteristics, they are applied in different ways and at different rates. Fuel Oil #2 may be applied with an emulsifier which aids in spreading the oil in a thin film over the breeding water. Rates used may range up to 10 gallons/acre. Flit MLO possesses constituents which causes it to spread over the water surface in a very thin layer. Flit MLO is usually applied as a fine spray at a rate of 1 to 5 gallons/acre.

Fuel oils may serve as solvents for various insecticides used in mosquito control. The resulting mixtures are correctly termed oil concentrates or solutions of insecticides. These

will be considered later in the section on insecticide formulations.

Group 2. Chlorinated Hydrocarbons. These compounds generally contain a significant amount of chlorine. DDT, chlordane, methoxychlor, and lindane are common examples. Although variously effective in controlling both adult and larval mosquitoes, chlorinated hydrocarbons tend to be persistent and accumulative allowing them to possibly build up in food chains. Because of this possible environmental hazard, chlorinated hydrocarbons are no longer recommended for use in mosquito control in New Jersey.

Group 3. Organophosphates. Most insecticides for mosquito control are members of this group. In contrast to the chlorinated hydrocarbons, the organophosphates are less persistent in the environment and have replaced the chlorinated hydrocarbons in mosquito control programs. The organophosphates as a group, are considered more hazardous to the applicator so that proper safety precautions as stated on the labeling should be carefully followed in all stages of application. Insecticides like malathion and naled (Dibrom®) are used as adulticides, while fenthion (Baytex®) and chlorpyrifos (Dursban®) can be used for both larvae and adults. Another, temephos (Abate®), can be used only as a larvicide. Each has its advantages and disadvantages, and the selection of a particular material depends on the type of control program, environmental factors, and cost, to name only a few. In selecting an insecticide, consult the current insecticide recommendations for mosquito control in New Jersey and read the label.

Group 4. Pyrethroids. The pyrethroids contain such compounds as pyrethrum, resmethrin, and allethrin. Pyrethrum is a botanical insecticide manufactured from certain flowers and has long been used as both an adulticide and larvicide. The low toxicity to man, rapid "knockdown" rate, and non-persistence in the environment make pyrethrum an important tool in mosquito control. Pyrethrum is quite toxic to fish and its use in fish-bearing waters should be avoided. Resmethrin and allethrin are synthetic pyrethroids. They differ slightly in chemical structure and in toxicity to various species of mosquitoes.

Group 5. Carbamates. This group of organic insecticides is similar to the organophosphates in the manner in which it is toxic to man. Both are cholinesterase inhibitors. Beyond this, carbamates are distinctive in several ways: (1) they are not adequate larvicides but are effective against adults and (2) they are difficult to formulate as liquids. With the exception of propoxur (Baygon®), insecticides in this group are not used to any great extent in mosquito control today. Presently, no carbamate insecticides are recommended for mosquito control in New Jersey.

Group 6. Insect Growth Regulators. The newest group of chemicals developed to control insects is termed the insect growth regulators (IGR) or the insect development regulators. Methoprene (Altosid®) and diflubenzuron (Dimilin®) are the two used in mosquito contol as larvicides. Methoprene (Altosid®) is a hormone-type compound which interferes with growth

in the 4th instar larval stage and affects pupation and the emergence of the adult. Diflubenzuron (Dimilin®) is not a hormone-type compound but interferes with the molting process by inhibiting an enzyme within the mosquito.

Herbicides

In following some water management procedures, it may be necessary to use herbicides. Because of their particular characteristics, herbicides should be used carefully and should be handled only by personnel with experience in their use.

Repellents

In the strictest sense, repellents are not insecticides. However, for personal protection outdoors, repellents may be quite effective if properly applied. Many of the commercially available repellents are formulated as creams, lotions, and aerosol sprays. Always check the labeling for an EPA registration number as this indicates that the product has been shown to be safe and effective.

In addition to proper application, the effectiveness of the repellent is dependent on such factors as the formulation, percentage of active ingredient, the activity of the person, and even the skin chemistry of the person using the repellent. The container labeling should be followed carefully if good results are to be expected and if possible hazards to the eyes, nose, and mouth avoided.

Insecticide Formulations

Many of the chemicals used against mosquitoes are generally

so effective that only a small amount is required for control. For example, only one-twentieth (1/20) of a pound of actual chemical per acre may be needed to control larvae. A major problem of such small dosages is uniformity of application. Greater uniformity in application is usually achieved by diluting the manufacturer's concentrated formulation. The resulting increase in total bulk or volume facilitates uniform coverage of the target area.

The following are the main formulations used in mosquito control.

1. High Concentrate Liquids. These insecticide formulations are very highly concentrated, sometimes as high as 95% and can be diluted with oil for application as a larvicide or adulticide. Various oils can be used as diluents, and other materials such as stabilizers can be added to the solution to insure the desired results. Because these concentrated materials are generally oil-based, water is not used as a diluent.

In some instances, the high concentrate liquids can be applied without further dilution in an ultra low volume (ULV) application. Here, the concentrated formulation is applied at rates as low as one fluid ounce per acre in microscopically small droplets which are intended to remain floating in the air for the purpose of contacting flying mosquitoes.

2. Emulsifiable Concentrates. These formulations, designated EC or E, differ from liquid concentrates in that they contain an emulsifier which allows them to be mixed with a

large quantity of water before being applied. They can be used as larvicides or as adulticides.

3. Granules. Granular formulations are dry, ready-to-use, low concentrate mixtures of insecticide and inert carriers. Granular insecticides are primarily used as larvicides. Because granules penetrate the vegetative cover over many larval habitats, they can be more effective than liquid formulations in some areas. The granules are scattered over the breeding water where they soon sink in the water and release the insecticide to kill the larvae.

4. Wettable Powders. Wettable powders are dry formulations of an insecticide and a wetting agent that are designed to be mixed with water. This suspension is sprayed on foliage or buildings and, after drying, leaves a residual coating to kill mosquitoes that rest on the treated surface. Although widely used in anti-malarial programs in other countries, this formulation is seldom used for mosquito control in New Jersey.

Application Equipment

Insecticide application equipment for mosquito control in New Jersey falls into two categories: sprayers and granular applicators. Granular applications are more commonly used for larviciding while sprays are used for both larviciding and adulticiding.

Application equipment ranges from small, compressed air sprayers to sophisticated aircraft delivery systems. The piece of equipment selected should do as wide a range of tasks as possible and do them well and safely. A generalized piece of

equipment should not be used if a poor or unsafe job results. The component parts of the application equipment, such as spray tanks, pumps, agitators, nozzles, and hoses should be chosen on the basis of meeting the task at hand effectively and safely. Proper maintenance and cleaning of the equipment will help insure its long wear and effective operation. Accurate calibration of equipment prior to each use is essential.

Application of Granular Formulations

Basically, all granular applicators are containers with adjustable openings in the base through which a controlled amount of granular insecticide may pass. They may be manually operated or power assisted. Some may be equipped with agitators or auger feeds to assist in producing a uniform flow rate. In New Jersey, granular application equipment is used primarily in larviciding programs.

The simplest device for applying granules is the horn seeder. The horn seeder is comprised of a canvas bag which is slung over the shoulder and a tapered, telescoping wand or tube is located at the lower front corner of the bag. Granules are dispersed as the operator's arm (and wand) move in a horizontal figure 8 fashion. Application rates may be altered by adjusting the opening at the base of the wand or by changing the speed at which the operator walks.

The cyclone-type spreaders are the second type of manually operated granular applicators. These are cylinders with an adjustable slot in the base through which granules fall

onto a rotating disc and are dispersed by centrifugal force. This disc is rotated by gears which are activated by turning a crank handle. The rate of dispersal may be altered by controlling the size of the slotted opening, or by changing the walking speed of the operator.

Both the cyclone-type spreaders and the horn seeder are commonly used in treating small, isolated breeding areas such as woodland pools.

The power assisted, blower-type granular applicators have feed tubes which meter the granules into the blast of an air blower. These blower-type spreaders may be back-pack size or truck mounted. The speed of the air blast may range from 75 to 150 mph. Similar blower-type spreaders are also utilized in helicopter delivery systems where the forward air speed of the aircraft is not high enough to provide adequate pressure for proper distribution of the granules. In fixed-wing aircraft, where the payload is greater, ram air-type spreaders are used which require no power other than the air being driven back by the propeller.

Application of Liquid Formulations

Liquid formulations for mosquito control can be applied in sprays which range in droplet size from less than 5 microns (fogs) to 250 microns (mists). Although the actual pieces of equipment are numerous, there are seven basic ways of applying liquid formulations for mosquito control.

1. Compressed Air Sprayers. One of the most common sprayers for treating small areas is the 1 to 2-gallon compressed air sprayer. The air in the upper portion of the spray tank

is put under pressure by a hand pump and the pressure created forces the spray through the nozzle. Compressed air sprayers are used for applying larvicides to small breeding areas such as catch basins or woodland pools.

2. Hydraulic Sprayers. In hydraulic sprayers, the spray mixture is taken into the pump, put under pressure, and forced through the nozzle. In some sprayers, pressures of up to 600 psi may be reached. Hydraulic sprayers range in size from a back-pack with a trombone sprayer to those which are truck mounted. This equipment is most often used for treating larger mosquito breeding areas.

3. Air Blast Sprayers. Air blast sprayers or mist blowers work somewhat like hydraulic sprayers but differ in that air carries the insecticide to the target. The tank mixture is introduced into a blast of air by a hydraulic pump. These type of sprayers range in size from a motor powered back-pack to those which are truck mounted. Air blast sprayers are used to apply both larvicides and adulticides over large areas.

4. Air-Liquid Mixing Chamber Applicators. This group contains the ULV-type applicators. Here, low pressure-high velocity air and low pressure liquid are introduced into a small swirl chamber in which shearing forces break up the liquid into extremely fine droplets. This type of equipment is usually truck mounted for ground use. ULV-type equipment may also be used in aircraft delivery systems.

5. Thermal Foggers. In thermal foggers, hot gasses and the atomized spray mixture combine in the cooler outside air to produce the fine particles of an insecticide fog. Thermal

foggers are only used to control adult mosquitoes.

6. Rotating Cylinder or Disc Applicators. This type of equipment uses high speed (10,000 rpm or more) rotating discs or cylinders to break up the liquid as it passes through a permeable sleeve (5 to 60 micron openings), through one or a series of screens, or as it passes between two closely spaced discs. In New Jersey, this type of equipment is aircraft mounted and used in adulticiding programs.

7. Aerosol Bombs. Aerosols or "bug bombs" consist of an insecticide and propellant in a pressurized container. Since they are normally purchased as a unit from the manufacturer, they are used without further mixing. Aerosol bombs are not very economical and are only used in small, confined areas.

Biological Control

Like all other organisms, mosquitoes have been subject to attack by predators and parasites for millions of years. Many viruses, bacteria, fungi, nematodes, and other invertebrate and vertebrate organisms naturally control mosquito populations to varying degrees. However, the use and manipulation of biological agents for controlling mosquito population levels is a fairly recent development and currently under considerable investigation. Although the future use of biological control agents holds promise, the present use of this technique has had only limited success.

Biological control procedures may be implemented by man in the following ways:

1. by modifying the mosquito's habitat so that naturally occurring enemies can be more effective.
2. by preserving natural enemies through limiting the use of chemicals or other control methods which might have an adverse effect on populations of these predators and parasites.
3. by introducing predators and parasites into a mosquito population.

By far the most successful biological control attempts have involved the introduction of predaceous fish into mosquito breeding areas as an adjunct of many water management projects. Predaceous fish are more effective against Culex and Anopheles mosquitoes which breed in more or less permanent bodies of water. The alternate drying and flooding needed for the hatching of Aedes mosquito eggs makes control with predaceous fish more difficult. The effectiveness of predaceous

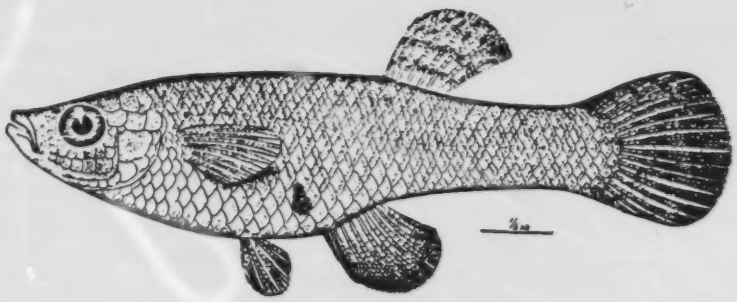


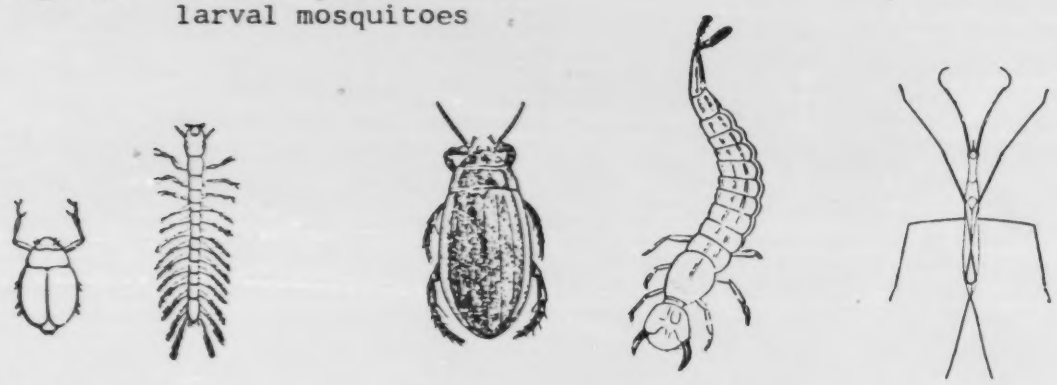
Fig. 25. The mosquito fish, Gambusia affinis

fish is thus enhanced by water management techniques which allow access of fish into breeding areas or by constructing permanent bodies of water such as ponds or impoundments where permanent fish populations can exist.

The mosquito fish, Gambusia affinis, has gained worldwide distribution because of its effectiveness as a mosquito predator. Salt marsh killifish and sheepshead minnows are effective if they are able to gain access into mosquito breeding areas. Other predaceous fish include the eastern mud minnow and the rainwater minnow.

Hydra and insects including backswimmers, water boatmen, waterscorpions, predaceous diving beetles, water striders, whirligig beetles, water scavenger beetles, and dragonfly naiads are natural predators of larval mosquitoes. Some natural enemies of adult mosquitoes include spiders, adult dragonflies, bats, swallows, purple martins, nighthawks, and frogs.

Fig. 26. Natural predators of larval mosquitoes



adult larva adult larva

whirligig beetle diving beetle waterscorpion

water boatman

water strider

Mechanical Control

Mechanical control procedures are most often used to prevent adult mosquitoes from entering dwellings or other structures and becoming a nuisance. Unlike many other control procedures, mechanical control may be carried out by the lay-person. Screening and caulking of windows and such enclosures as porches may substantially reduce mosquito annoyance indoors.

Integrated Control

Integrated control refers to the combined use of several methods (chemical, water management, biological, or mechanical) to control a pest. Often, an "integrated" approach will give the best results and be less expensive in the long run.

Integrated control procedures in mosquito control programs are numerous and perhaps may be best illustrated by the following example. Given a situation where several mosquito breeding depressions exist adjacent to a natural creek on a salt marsh, several control methods may be used. Assuming all

conditions are favorable for such an approach, ditches may be constructed from the tidal creek to the breeding depressions. The resulting constant tidal fluctuations will put stress on the larvae of Aedes mosquitoes. Since Aedes eggs must undergo a period of drying, the daily flooding of the breeding depressions may adversely affect hatching. This water management practice will also allow predaceous fish (biological control) to enter these areas should conditions favoring mosquito breeding (such as extended periods of flooding) occur. Larvicides may be used to control existing populations so that they will not become a nuisance factor prior to completing water management procedures. Larval mosquitoes which survive the various control attempts and emerge, may then be controlled by the application of an adulticide. Thus, the combined use of water management and biological control methods in this situation increases the chances for effective control before the mosquito becomes a nuisance or possible disease vector. Although applications of insecticides may become necessary, the number of such treatments will be greatly reduced. Once implemented, this system is virtually self-maintaining, and with the exception of an occasional, necessary insecticide application, the cost is minimal.

Public Relations

Organized mosquito control necessitates a continuous and factual public relations program. Control effectiveness will depend in large part on public support.

The prerequisites to such a program include proper plan-

ning, trained personnel, and proper equipment. Of course, all these are necessary for doing a good job, and the best public relations is good mosquito control.

Public relations is an educational process that should be a two-way activity. Mosquito control personnel should not only inform the public of their program but also listen to the public and learn what it expects. The public should be so informed so that it:

1. recognizes the problems.
2. recognizes the causes of the problems.
3. knows the approach to correct the problems.
4. knows the reasons for successes or failures.
5. knows how to assist mosquito control personnel and help itself.

Mosquito control personnel should listen to the public so that they:

1. learn of problem areas.
2. learn which methods are acceptable and unacceptable to the people living in the problem area.
3. obtain feedback as to the effectiveness of control efforts.

Public relations may be approached by:

1. person-to-person contacts, including phone calls, letters, and home visits.
2. group contacts, including lectures, tours, field trips, and school visits.
3. mass media activities, including radio, television, newspapers, and exhibits.

It behooves those responsible for mosquito control programs to explore all three approaches.

Information concerning mosquito control programs should

also extend to other government agencies. Health departments, planning boards, road departments, environmental commissions, and other state, county, and municipal bodies may have an interest in mosquito control projects and activities. It may be advantageous to discuss problems and tentative plans with these agencies. Water management projects especially should be planned so as to serve the objectives of all concerned agencies. Inter-agency cooperation is beneficial to a mosquito control program because an informed, cooperating outside agency then becomes another means of keeping the public aware of the benefits of mosquito control.

ACKNOWLEDGEMENTS

The editors wish to acknowledge the following people for their assistance and contributions to this manual.

Mr. Patrick Slavin, Chairman
Mr. Jere Downing
Mr. Herman Ehrenberg
Mr. Thomas Sellers
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OF NEW JERSEY

CPA CATEGORY NO. 8B
MOSQUITO CONTROL

STUDY QUESTIONS FOR COMMERCIAL PESTICIDE APPLICATORS

Office of Pesticide Applicator Training

COOPERATIVE EXTENSION SERVICE / COOK COLLEGE

CPA Category # 8B - Mosquito Control

STUDY QUESTIONS

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ACKNOWLEDGEMENTS

The authors wish to acknowledge the following people for their contributions to these study questions.

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TABLE OF CONTENTS

Contents	Pages
Acknowledgements	i
Table of Contents	ii
Introduction	iii
Identification	1
Mosquito Biology, Habits, and Habitats	2-4
Mosquitoes as Vectors of Disease	4-5
Survey Methods	5-6
Control	6-11
Water Management	6-7
Chemical Control	8-9
Application Equipment	9-10
Mechanical Control	10
Biological Control	10-11
Integrated Control	11

INTRODUCTION

This category Study Questions Leaflet is for the use of the commercial pesticide applicator preparing for certification as required by federal and state pesticide regulations. The main objective in providing this publication to pesticide users and applicators is to insure the proper and safe use of these chemicals. By putting to use the best technology in applying pesticides we know significant benefits are possible for the applicator as well as the environment. Greater economy, more efficiency in pest control, less risk of hazards, and less time needed in the application of pesticides are some of the benefits available to applicators participating in training for certification.

The multiple choice and true-false questions relate to the main points in the category area of pesticide application and should be studied with reference to the Pesticide Applicator Training Manual. Study and complete each chapter before going to the next. Answer the Category Study Questions by choosing the best answer. Refer to the key for the correct answers.

The following suggestions may be helpful in the study of these Category Study Questions and associated Pesticide Applicator Training Category Manual:

1. Try to be in a positive frame of mind that these materials can be of considerable help to you.

2. Pick a quiet place to study and a time when two or more chapters can be studied at one sitting.

3. Do not memorize. Try to understand the idea and/or principle back of each question.

4. Additional help is as close as your telephone. If you do not understand some questions, your County Agents, specialists, fieldmen, and others may be able to help. Sign up for a training session for pesticide applicators.

5. Do not cram. Choose regular times for study.

6. A training school may be available in your county or area. Call your County Extension Office for information.

7. Relax and be confident when you take the exam.

CERTIFICATION CAN BE THE STAMP OF PROFESSIONALISM IN YOUR WORK

COMMERCIAL PESTICIDE APPLICATOR - CATEGORY #8B STUDY QUESTIONS

Section 1. Identification

1. Which of the following characteristics best describe adult female mosquitoes? a( ) b( ) c( )
   a. one pair of wings with numerous scales on the edges and veins and piercing-sucking mouthparts
   b. two pairs of net-veined wings and piercing-sucking mouthparts
   c. one pair of clear wings, elbowed antennae, and chewing mouthparts

2. Male and female mosquitoes may be separated by the appearance of their antennae and mouthparts. T( ) F( )

3. Adult female mosquitoes whose palpi appear to be the same length as the proboscis belong to which of the following genera? a( ) b( ) c( ) d( )
   a. Aedes
   b. Anopheles
   c. Culex
   d. Psorophora

4. Larvae with relatively slender air tubes and several tufts or single hairs on their air tubes belong to which of the following genera? a( ) b( ) c( )
   a. Anopheles
   b. Aedes
   c. Culex

5. The larvae of which of the following genera have no air tubes? a( ) b( ) c( )
   a. Aedes
   b. Anopheles
   c. Culex

6. An adult mosquito having an abdomen with a blunt tip and mixed dark and pale, broad wing scales would belong to which of the following genera? a( ) b( ) c( ) c( )
   a. Aedes
   b. Coquillettidia
   c. Culiseta
   d. Culex

KEY

1. a
2. T
3. b
4. c
5. b
6. b

Section 2. Mosquito Biology, Habits, and Habitats

1. Mosquitoes are important pests because they- a( ) b( ) c( ) d( )
   a. are annoying and cause discomfort by biting.
   b. may become disease vectors.
   c. may adversely affect the economy of the state.
   d. all of the above

2. Mosquitoes undergo complete metamorphosis and thus develop through- a( ) b( ) c( )
   a. egg, nymph, and adult.
   b. egg, larva, pupa, and adult.
   c. egg, larva, nymph, and adult.

3. Adult female mosquitoes, according to genus, lay their eggs- a( ) b( ) c( ) d( )
   a. singly with a float.
   b. singly without a float.
   c. in an egg raft.
   d. all of the above

4. All mosquito larvae are aquatic. T( ) F( )

5. Most mosquito larvae must continually return to the water surface to obtain air. T( ) F( )

6. Mosquito larvae obtain air through their- a( ) b( ) c( )
   a. mouths. b. siphons or air tubes.
   c. breathing "trumpets."

7. Mosquito larvae molt- a( ) b( ) c( ) d( )
   a. only once. b. twice.
   c. 4 times. d. at least 6 times.

8. Mosquito pupae breathe through their- a( ) b( ) c( )
   a. mouths. b. siphons or air tubes.
   c. breathing "trumpets."

9. Mosquito pupae- a( ) b( ) c( ) d( )
   a. are quite active and feed constantly.
   b. are active but do not feed.
   c. rarely move but feed on small particles which float near them.
   d. none of the above

10. Both male and female mosquitoes feed on blood. T( ) F( )

11. Some species of mosquitoes prefer to feed on one type of animal while others may take blood from a number of different animals. T( ) F( )

12. The females of all species of mosquitoes in New Jersey must first obtain a blood meal before producing eggs. T( ) F( )

13. Female mosquitoes may live long enough to produce several batches of eggs. T( ) F( )

14. The type or quality of water has no bearing on the species of mosquito which may eventually breed there. T( ) F( )

15. Which of the following is considered a semi-permanent body of water? a( ) b( ) c( )

a. a freshwater swamp
b. a salt marsh pool
c. a woodland pool

16. In New Jersey, woodland pool mosquitoes generally have only one generation per year. T( ) F( )

17. The most important woodland pool mosquito in New Jersey is- a( ) b( ) c( ) d( )

a. Aedes canadensis. b. Culex pipiens.
c. Aedes vexans. d. Aedes sollicitans.

18. Floodwater mosquitoes have only one generation per year. T( ) F( )

19. The most important fresh floodwater mosquito in New Jersey is- a( ) b( ) c( ) d( )

a. Aedes canadensis. b. Culex pipiens.
c. Aedes vexans. d. Aedes sollicitans.

20. For floodwater mosquitoes, the frequency and amount of rainfall during the spring and summer months has a direct bearing on the number of generations per year. T( ) F( )

21. Salt marsh mosquitoes breed in- a( ) b( ) c( )

a. tidal creeks and mosquito ditches.
b. depressions in the salt marsh which periodically fill with water.
c. beer cans and other debris found near the coastline.

22. The most important salt marsh mosquito in New Jersey is- a( ) b( ) c( ) d( )

a. Aedes canadensis. b. Culex pipiens.
c. Aedes vexans. d. Aedes sollicitans.

23. The larvae of Coquillettidia perturbans are especially unique in that they- a( ) b( ) c( )

a. are predators of small fish.
b. obtain air by inserting their pointed air tubes into the roots of some aquatic plants.
c. take several years to complete their life cycle.

24. Which of the following is not considered a freshwater swamp mosquito? a( ) b( ) c( )

a. Coquillettidia perturbans
b. Aedes vexans
c. Culiseta melanura

25. Some freshwater swamp mosquitoes overwinter as- a( ) b( ) c( )

a. pupae.
b. larvae which survive the winter in suspended animation within the ice.
c. hibernating adults.

26. In which of the following habitats would you not expect to find Culex pipiens larvae? a( ) b( ) c( ) d( )

a. street catch basins
b. an old paint can
c. a swamp polluted with industrial waste
d. a salt marsh depression

KEY

1. d	8. c	15. a	22. d
2. b	9. b	16. T	23. b
3. d	10. F	17. a	24. b
4. T	11. T	18. F	25. c
5. T	12. F	19. c	26. d
6. b	13. T	20. T	
7. c	14. F	21. b	

Section 3. Mosquitoes as Vectors of Disease

1. Mosquitoes can be effective disease vectors because- a( ) b( ) c( )

a. they may feed on a number of animals throughout their lives.
b. they frequently visit garbage and other filth.
c. they breed in manure.

2. Culiseta melanura plays an important role in the disease cycle of Eastern equine encephalitis by- a( ) b( ) c( )

   a. feeding on infected birds and then biting man and transmitting the virus.
   b. feeding on an infected person and transmitting the virus to other humans.
   c. transmitting the virus from bird to bird.

3. Both malaria and yellow fever are important mosquito-borne diseases in New Jersey today. T( ) F( )

4. St. Louis encephalitis is transmitted to man by- a( ) b( ) c( ) d( )

   a. Culex pipiens. b. Aedes vexans.
   c. Aedes sollicitans. d. none of the above

5. Which of the following mosquitoes is suspected of being the major vector of Eastern equine encephalitis? a( ) b( ) c( ) d( )

   a. Aedes canadensis b. Culex pipiens
   c. Aedes sollicitans d. all of the above

6. Like St. Louis encephalitis, the causal agent of dog heartworm is a virus. T( ) F( )

7. Dog heartworm is found only in dogs which frequently go outdoors. T( ) F( )

8. Presently, the mosquito vector(s) of dog heartworm are unknown. T( ) F( )

Key

1. a	5. c
2. c	6. F
3. F	7. F
4. a	8. T

Section 4. Survey Methods

1. The New Jersey light trap is a useful method for surveying both adult and larval mosquitoes. T( ) F( )

2. Generally, both landing counts and pigeon baited traps measure only female mosquitoes which are seeking blood. T( ) F( )

3. One of the limitations of using pigeon baited traps is that they sample only those mosquito species which feed on birds. T( ) F( )

4. Of the adult surveillance methods listed below, which is the <u>least</u> selective with respect to species, sex, and whether or not the females are seeking blood? a( ) b( ) c( ) d( )

   a. pigeon baited traps b. landing counts
   c. truck traps d. N.J. light traps

5. Larval populations of most species of mosquitoes may be sampled using a one pint dipper. T( ) F( )

6. Besides determining the species of mosquito present, adult mosquito surveillance data is of little value in mosquito control programs. T( ) F( )

KEY

1. F	4. c
2. T	5. T
3. T	6. F

Section 5. Control

<u>Water Management</u>

1. Water management is probably the most effective and widely used method of controlling mosquitoes in New Jersey. T( ) F( )

2. Water management is directed towards the aquatic stages of mosquitoes. T( ) F( )

3. In selecting the type of water management method to be used in a particular situation, the ecosystem should always receive primary consideration. T( ) F( )

4. Successful restoration programs may involve the removal of debris and silt which may accumulate in streams and rivers. T( ) F( )

5. An example of source reduction would be the removal of excess surface water which may serve as mosquito breeding habitats. T( ) F( )

6. Examples of source reduction include- a( ) b( ) c( ) d( )
   a. landfills.
   b. grading or filling in of mosquito breeding areas.
   c. restoration projects.
   d. all of the above

7. Parallel ditching is one of the new, effective methods of salt marsh water management in New Jersey. T( ) F( )

8. The average person can do nothing to reduce mosquito breeding around the home. T( ) F( )

9. Which of the following is <u>not</u> a salt marsh water management technique? a( ) b( ) c( ) d( )
   a. ditching b. impounding
   c. larviciding d. ponding

10. The extent and location of mosquito breeding areas are important factors to consider when selecting a particular water management technique. T( ) F( )

11. The construction of ponds and impoundments may be useful in controlling mosquitoes but the cost of construction exceeds the benefits derived. T( ) F( )

12. The main purpose of constructing ponds and impoundments is to- a( ) b( ) c( )
   a. create new recreational areas.
   b. create semi-permanent bodies of water which will support populations of mosquito-eating fish.
   c. provide work for mosquito control personnel during the winter.

13. Once impoundments are constructed, little can be done to control undesirable vegetation. T( ) F( )

14. To comply with federal and/or state regulations, permits must be obtained before most water management programs are begun. T( ) F( )

KEY

1. T	5. T	9. c	13. F
2. T	6. d	10. T	14. T
3. T	7. F	11. F	
4. T	8. F	12. b	

Chemical Control

1. All insecticides used for mosquito control are effective in killing both larvae and adults. T( ) F( )

2. Inorganic insecticides are generally- a( ) b( ) c( )
   a. stomach poisons. b. systemics.
   c. nerve poisons.

3. Oils may act as- a( ) b( ) c( ) d( )
   a. larvicides.
   b. solvents for some insecticides.
   c. either a. or b.
   d. neither a. nor b.

4. Chlorinated hydrocarbon insecticides are used frequently in New Jersey to control mosquitoes. T( ) F( )

5. The main objection to using chlorinated hydrocarbon insecticides is that they are- a( ) b( ) c( ) d( )
   a. persistent and tend to build up in food chains.
   b. quite expensive.
   c. not very effective.
   d. extremely hazardous to the applicator.

6. Most of the insecticides currently used in mosquito control in New Jersey are organophosphates. T( ) F( )

7. Which of the following is not an organophosphate insecticide? a( ) b( ) c( ) d( )
   a. malathion b. pyrethrum
   c. Abate® d. Dibrom®

8. Although less persistent, organophosphates as a group, are generally considered to be more hazardous to the applicator than chlorinated hydrocarbon insecticides. T( ) F( )

9. Which of the following groups contains insecticides which are cholinesterase inhibitors? a( ) b( ) c( )
   a. chlorinated hydrocarbons
   b. organophosphates
   c. pyrethroids

10. Which of the following statements concerning pyrethroids is false? a( ) b( ) c( )
   a. pyrethroids exhibit low toxicity to man
   b. pyrethroids tend to build up in food chains
   c. pyrethroids have rapid "knockdown" action

11. Pyrethroids are usually highly toxic to fish. T( ) F( )

12. Dimilin® and Altosid® are used only as larvicides. T( ) F( )

13. Like the organophosphates, the carbamate insecticides are also cholinesterase inhibitors. T( ) F( )

14. The term ultra low volume (ULV) refers to the application of- a( ) b( ) c( )

    a. high concentrate liquids in very small amounts.
    b. high concentrate liquids in very large amounts.
    c. low concentrate liquids in very large amounts.

15. Which of the following formulations is usually applied without further dilution? a( ) b( ) c( )

    a. wettable powders b. granules
    c. emulsifiable concentrates

KEY

1. F	5. a	9. b	13. T
2. a	6. T	10. b	14. a
3. c	7. b	11. T	15. b
4. F	8. T	12. T	

Application Equipment

1. Application rates of granular insecticides applied with a horn seeder may be changed by- a( ) b( ) c( )

    a. adjusting the wand opening and changing the speed at which the applicator walks.
    b. changing the length of the wand and the size of the bag.
    c. changing the direction of travel.

2. Application rates of granular insecticides applied with a cyclone-type spreader may only be changed by altering the speed at which the applicator travels. T( ) F( )

3. In blower-type, power assisted granular spreaders, both air and water may be used to deliver the insecticide to the target. T( ) F( )

4. One of the major disadvantages of using granular formulations is that they can only be applied by ground equipment. T( ) F( )

5. Air blast sprayers work somewhat like hydraulic sprayers but differ in that air carries the insecticide to the target. T( ) F( )

6. Thermal foggers can be used to control both adult and larval mosquitoes. T( ) F( )

7. A generalized piece of application equipment is usually the best type to purchase providing the results are good and the equipment is safe. T( ) F( )

8. With certain modifications, blower-type granular spreaders may be used for aerial applications. T( ) F( )

KEY

1. a	5. T
2. F	6. F
3. F	7. T
4. F	8. T

Mechanical Control

1. The main objective of mechanical control is to prevent mosquitoes from entering dwellings and other structures. T( ) F( )

2. Which is not an example of mechanical control? a( ) b( ) c( ) d( )

   a. screening b. swatting
   c. aerosol bombs d. caulking

KEY

1. T 2. c

Biological Control

1. The most successful biological control organisms used in mosquito control are predaceous fish. T( ) F( )

2. The concept of using natural enemies to control mosquitoes has been developed within the last 10 years. T( ) F( )

KEY

1. T 2. F

Integrated Control

1. One of the major disadvantages of an integrated control program is that it requires constant maintenance. T( ) F( )

2. An example of an integrated control program would be the use of- a( ) b( ) c( )

   a. an insecticide, water management, and biological control.
   b. screening and caulking of windows.
   c. ponding, ditching, and source reduction.

3. Since mosquito control is mandated by law in New Jersey, there is little use in maintaining good public relations. T( ) F( )

KEY

1. F 3. F
2. a